PHYTOTOXICOLOGY ASSESSMENT SURVEY INVESTIGATION IN THE VICINITY OF ALLIED CHEMICAL CANADA LIMITED AND GENERAL CHEMICAL CANADA LIMITED AMHERSTBURG, ONTARIO - 1987

JULY 1990

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1 Executive Summary

In 1987, the Phytotoxicology Section conducted a vegetation survey in the vicinity of the industrial complex occupied by Allied Chemical Canada Limited (ACCL) and General Chemical Canada Limited (GCCL) in Amherstburg, Ontario. This survey consisted of multiple samplings of silver maple foliage for chemical analysis and visual ratings of the severity of foliar injury attributable to atmospheric emissions from the industries. These activities were conducted at nine permanent stations at the end of the months of May through September.

The results of chemical analysis indicated highly elevated concentrations of fluorine, sodium and chlorine; in excess of the Phytotoxicology Section Upper Limits of Normal guidelines for unwashed foliage. Washed foliage from one station contained fluorine concentrations in excess of former Control Order limits on each sampling date.

The sources of these contaminants could be traced to the industrial complex, although a second industrial source of chlorine in the geographic area precluded ascribing all of the chlorine contamination to the ACCL/GCCL complex.

Visual examination of silver maple foliage frequently revealed trace levels of injury characteristic of fluoride or sodium chloride exposure. However, due to the similarity of injury symptoms caused by these contaminants, it was not possible to attribute the injury to one or the other.

A review and analysis of foliage chemistry data derived from six of the nine stations which have been active since 1975 indicated continuous and environmentally unacceptable contamination of silver maple foliage by emissions ascribed to the two companies. The consistent and excessive degree of foliar contamination during the past 12 years indicates that emission control initiatives at this industrial complex have not provided adequate protection to the surrounding terrestrial environment.

2 Introduction

2.1 Industrial Sources

Allied Chemical Canada Ltd. (ACCL) began operating at its Amherstburg plant location in 1919 to produce sodium carbonate. By 1985 the plant was involved in the production of four principal chemical products:

1. Sodium carbonate (Na_2CO_3) is produced from salt (NaCl) and limestone ($CaCO_3$) using an ammonia catalyst. Operation began in 1919.
2. Calcium chloride dihydrate ($CaCl_2.2H_20$) is produced through the refining of the calcium chloride and salt solution by-products from the sodium carbonate production. Operation began in 1934.
3. Fluorocarbons are produced from a reaction of hydrofluoric acid (HF) and carbon tetrachloride (CCl_4), with hydrochloric acid (HCl) as a by-product. Operation began in 1965.
4. Hydrofluoric acid (HF) is produced from a reaction of sulphuric acid (H_2SO_4) and fluorspar (CaF_2), with gypsum ($CaSO_4$) as a by-product. Operation began in 1971.

In 1986, a corporate reorganization resulted in the retention of the hydrofluoric acid and fluorocarbon production facilities by ACCL and the acquisition of the sodium carbonate and calcium chloride production facilities by General Chemical Canada Ltd. (GCCL). Both companies maintain operations at the same physical location, with GCCL assuming control of those parts of the physical plant related to sodium carbonate and calcium chloride production.

At some point in time, presumably after the reorganization, ACCL acquired the corporate name Allied Chemicals Canada Incorporated. For the purpose of this report, all references to Allied Chemical Canada Limited or ACCL should be interpreted as referring to the company now known as Allied Chemicals Canada Incorporated.

In 1982, a new industrial operation was established at a site immediately east of the ACCL/GCCL complex. Canada Occidental Petroleum Ltd. (formerly BCM Technologies Ltd. and now known as CanadianOxy Industrial Chemicals Limited Partnership) produces sodium chlorate ($NaClO_3$) by electrolysis of salt (NaCl) in an aqueous solution and oxidation of intermediate products to produce the sodium chlorate with H_2 gas as a byproduct. Principal fugitive emissions consist of gaseous chlorine and particulate salt and sodium chlorate from the receiving and shipping operations (Luyt, 1986).

The proximity of this new industry to the ACCL/GCCL complex and the similarity of potential emissions, with respect to common chemical elements, must, therefore, be acknowledged in the interpretation of environmental contamination ascribed to the ACCL/GCCL complex.

2.2 Phytotoxicology Section Surveys

The Phytotoxicology Section initiated vegetation surveys in the vicinity of the ACCL/GCCL industrial complex in 1970. The initial survey was a pre-operational background survey prior to the operation of the hydrofluoric acid production facilities. Vegetation monitoring surveys have since been conducted annually, during the summer growing periods. These surveys were designed to detect excessive concentrations of chemical elements in vegetation as a result of emissions from the industrial complex, as well as to identify occurrences of injury to vegetation which could be attributed to aerial exposure to specific elements or compounds used or produced at the industrial complex.

Vegetation surveys conducted in 1971 through 1973 revealed fluorine concentrations in vegetation which were highly elevated when compared to the pre-operational survey of 1970. Fluoride induced injuries to native vegetation and to gladiolus indicator plants were also observed (Linzon et al., 1973).

2.3 Control Orders

In 1974, ACCL was served with a Control Order under the Environmental Protection Act which set limits on the concentrations of fluorine which could be encountered in forage (grass) in the vicinity of the hydrofluoric acid production facility. A new Control Order was served in 1975 setting limits for fluorine concentrations in forage and silver maple foliage. This Control Order was in effect until 1977. Finally, in 1978 the third Control Order was served on ACCL. This Control Order was identical to the one served in 1975, except for the period of coverage.

This latest order, served on July 13, 1978, addressed the operation of the hydrofluoric acid plant. The order directed that emissions from the plant were to stop by discontinuing the operation of the plant upon notice from the Ministry of the Environment that the following conditions occurred:

1. Concentration of fluorine in unwashed forage collected within 3000 metres of the source exceeded 80 ppm in any one month of May through October.
2. Concentration of fluorine in unwashed forage collected within 3000 metres of the source exceeded an average of 60 ppm in any two consecutive months of May through October.
3. Concentration of fluorine in washed silver maple foliage collected within 3000 metres of the source exceeded 100 ppm in any one month of May through October.

However, the Control Order also stated that plant operations could continue if the Director was satisfied that concentrations for the remaining months would not be exceeded.

This latest order expired on October 31, 1978 and no other has been served to this date. Although the limits to the fluorine concentrations in vegetation set forth in the various Control Orders were exceeded before and during the

tenure of the Control Orders, and have continued to be regularly exceeded subsequent to the expiration of the 1978 Control Order, ACCL has not been ordered to suspend operations of the HF plant or related processes. The foliar contamination was not considered a threat to human health and therefore could not legally serve as a basis for plant shutdown.

3 1987 Phytotoxicology Vegetation Survey

3.1 Sampling Stations and Dates

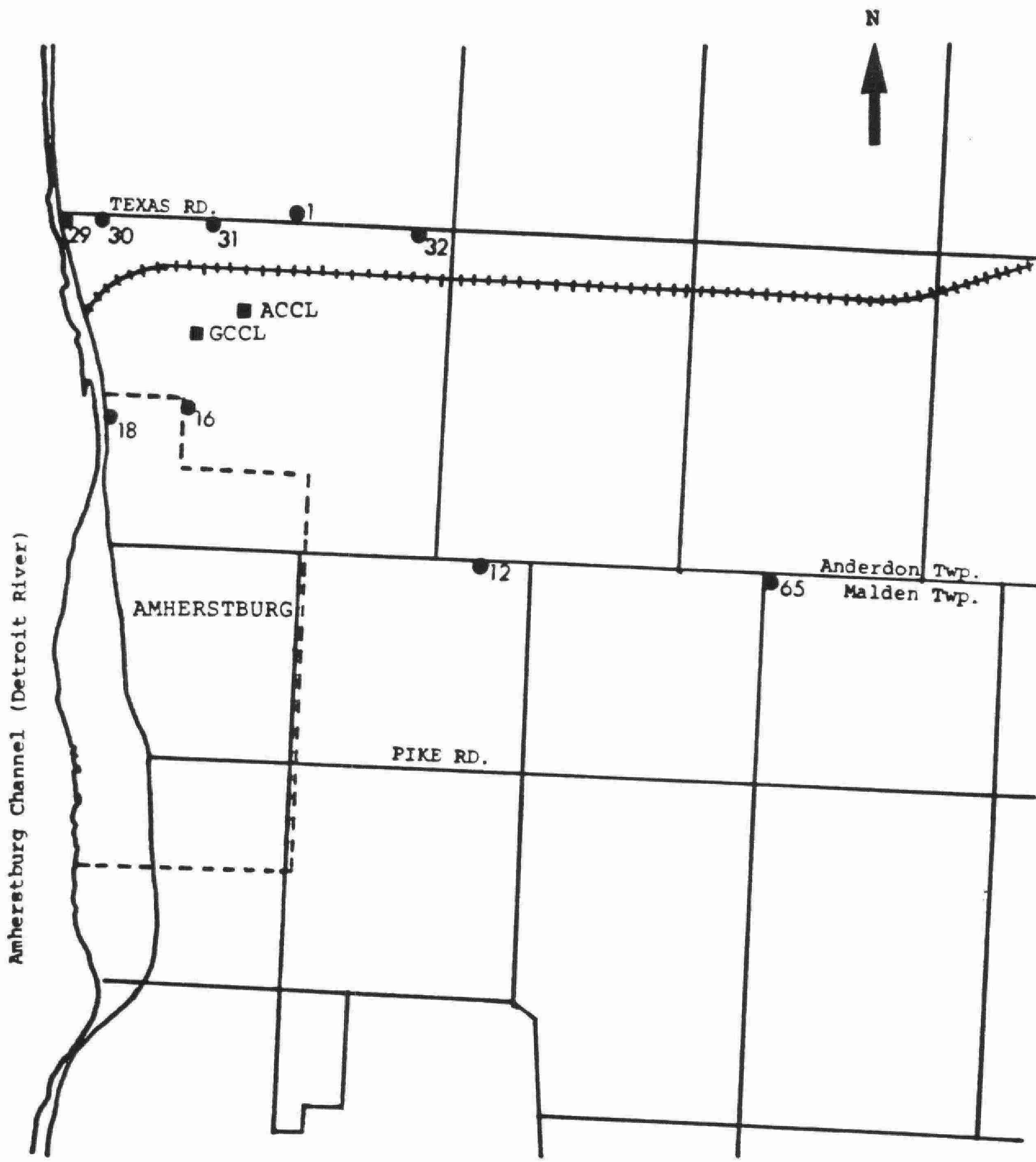
In 1987, the Phytotoxicology vegetation monitoring survey consisted of sampling silver maple (*Acer saccharinum*) foliage for chemical analysis and visually estimating the degree of foliage injury attributable to sodium chloride or fluoride exposure. There were nine stations in the survey, each consisting of a single sample tree which was sampled and visually assessed at the end of each month of May through September. Actual sampling and assessment dates were May 28, June 29, July 28, August 31 and September 30.

The locations of these stations are indicated in Figure 1 and the distances and compass bearings from the hydrofluoric acid plant are contained in Table 1. The HF plant was used as a reference point only and does not imply that it is the only source of atmospheric emissions within the industrial complex occupied by the two companies. The 1987 survey was unique since only silver maple foliage samples were collected at the end of each month. Previous surveys also involved collections of forage samples and included maple foliage collections from an expanded station network in August.

Table 1: Survey Stations - ACCL/GCCL Survey, 1987

Station Number	Distance (m)	Azimuth
1	590	30° NNE
12	1930	136° SE
16	640	212° SSW
18	980	231° SW
29	1160	295° WNW
30	970	302° WNW
31	500	336° NNW
32	1070	66° ENE
65	3300	114° ESE

Figure 1: Survey Stations - ACCL/GCCL Survey, 1987



■ ACCL = HF plant

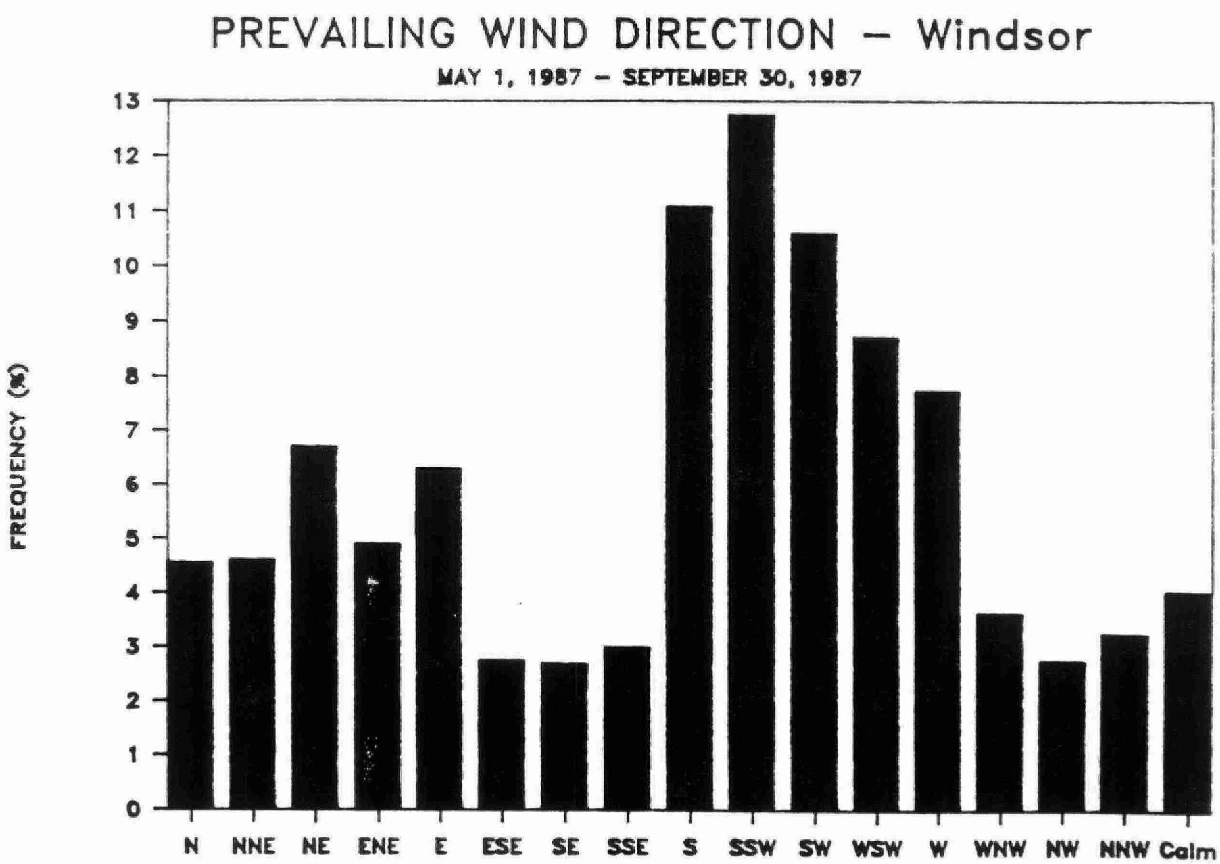
■ GCCL = $NaCO_3$ & $CaCl_2$ plant

●16 = Silver Maple Sampling Site

3.2 Prevailing Winds

Prevailing surface wind directions are critical to the distribution of emissions from the source industries. The nearest location, to the complex, where wind is recorded is at the Windsor airport. Figure 2 represents a frequency distribution of prevailing winds at Windsor and was compiled from hourly observations from May to September, 1987. These data were obtained from the Environment Canada, Atmospheric Environment Service, Monthly Meteorological Summary reports.

FIGURE 2



3.3 Foliage Sampling and Processing

Sampling consisted of cutting several foliated branches from the side of the tree facing the industrial complex using tree pruners on extension poles. The foliage from each branch was removed by latex-gloved hand and placed into polyethylene bags along with appropriate labels. Three replicate samples were obtained at each station.

The samples were transported to the Phytotoxicology Section sample processing laboratory where half of the foliage from each bag was subjected to a wash in a distilled water solution of 0.05% NaEDTA and 0.05% Alconox™ detergent followed by three separate rinses with distilled water. Both washed and unwashed subsamples were transferred to kraft paper bags and dried in a forced air oven at 80°C. Dry samples were ground in a stainless steel Wiley mill to pass through a 1 mm screen and collected in flint glass jars.

3.4 Injury Observations

At the time of sampling, the degree of injury to the foliage on the sampled branches was determined visually. Injury symptoms which consisted of a browning or blackening of the terminal margins were considered to be induced by fluoride or salt exposure. Injury ratings are, therefore, based on the foliage ultimately used for chemical analysis. Rating the injury to the collective foliage on the whole tree from ground level would not be reliable due to visibility constraints and was not attempted.

3.5 Foliage Chemical Analysis

Chemical analysis of the samples was performed by the MOE Laboratory Services Branch. Detailed analytical methods are contained in MOE (1983). In brief, the methods were as follows. Calcium and sodium were determined on strong acid digestions of the samples by Inductively Coupled Plasma

Emission and Atomic Emission Spectrophotometry, respectively. Chlorine was determined by X-Ray Fluorescence Spectrophotometry. Fluorine was determined by Ion Selective Electrode on a 0.1 N perchloric acid sample extraction. Concentrations of the four elements were determined in the unwashed subsamples. Only fluorine was determined in the washed subsamples.

4 Results

4.1 Foliage Chemistry

The element concentration arithmetic means and standard deviations for each set of triplicate samples are tabulated for each sampling date and station in Table 2. All concentration data in this report are on a dry sample weight basis. It should be noted that, in a few cases, the concentrations of fluorine in washed and unwashed subsamples collected at the most distant station, Station 65, were reported as below the detection limits of 4 or 5 ug/g. For statistical analysis purposes, these data points were assigned values of one half of the reported detection limit. These estimated data points have been integrated into the Table 2 data summary and subsequent statistical analyses and graphic representations.

The element concentration means for each set of triplicate samples collected at each sampling station are graphically presented, by the month of sampling, in a series of five histograms, Figures 3 through 7. These represent the four elements in unwashed foliage and fluorine in washed foliage.

These histograms also contain indicators on the concentration axes which represent the Phytotoxicology Section Upper Limit of Normal Guidelines for urban (ULNu) and rural (ULNr) unwashed foliage samples, where such guidelines have been established. The washed fluorine histogram (Figure 7) contains an indicator (CO) at the 100 ppm mark of the concentration axis representing the maximum acceptable fluorine concentration in washed silver maple foliage as directed in the 1978 Control Order discussed previously.

Table 2: Silver Maple Foliage Chemistry - ACC[illegible]CL Survey, 1987

	Ca (ug/g) Mean	Ca (ug/g) S.D.	Na (ug/g) Mean	Na (ug/g) S.D.	Cl (%) Mean	Cl (%) S.D.	F uw (ug/g) Mean	F uw (ug/g) S.D.	F w (ug/g) Mean	F w (ug/g) S.D.
May 28										
Stn. 01	8400	927	457	94	0.20	0.01	346	49	194	38
Stn. 12	7567	998	79	9	0.07	0.00	15	2	8	1
Stn. 16	8400	698	187	17	0.38	0.03	69	8	38	2
Stn. 18	6100	510	170	22	0.17	0.02	59	6	29	6
Stn. 29	6967	858	250	37	0.24	0.00	29	2	17	4
Stn. 30	6933	499	507	78	0.17	0.02	44	2	18	2
Stn. 31	9867	189	1733	170	0.34	0.03	156	25	61	3
Stn. 32	7000	1639	110	8	0.08	0.01	44	1	32	2
Stn. 65	6733	634	27	3	0.11	0.01	4	2	3	2
June 29										
Stn. 01	7167	896	370	50	0.23	0.02	212	16	126	40
Stn. 12	11333	471	74	8	0.11	0.02	13	1	9	1
Stn. 16	10333	943	130	24	0.33	0.05	33	7	24	3
Stn. 18	6767	624	127	9	0.34	0.03	36	3	27	1
Stn. 29	10100	698	47	3	0.21	0.01	29	3	21	2
Stn. 30	7800	535	140	16	0.12	0.01	19	3	13	1
Stn. 31	10467	2317	533	119	0.24	0.04	74	8	51	6
Stn. 32	10333	2604	123	12	0.10	0.00	42	6	35	5
Stn. 65	8267	330	31	1	0.35	0.01	10	0	8	0
July 28										
Stn. 01	8567	2444	620	29	0.35	0.05	311	67	161	25
Stn. 12	10733	1969	440	54	0.13	0.01	11	1	9	0
Stn. 16	14333	471	127	19	0.40	0.05	34	2	18	2
Stn. 18	10333	1247	98	26	0.25	0.02	29	9	18	2
Stn. 29	13667	471	120	0	0.28	0.04	95	15	42	6
Stn. 30	10800	1883	112	14	0.08	0.02	43	7	14	2
Stn. 31	13667	2055	327	39	0.26	0.05	86	11	29	9
Stn. 32	12367	2310	113	12	0.11	0.00	42	4	28	1
Stn. 65	11000	816	26	4	0.49	0.05	8	0	4	2
August 31										
Stn. 01	10533	660	207	45	0.40	0.01	203	9	153	17
Stn. 12	13333	471	78	7	0.16	0.01	14	0	13	1
Stn. 16	11333	471	393	111	0.57	0.05	34	6	26	3
Stn. 18	13333	2055	172	62	0.35	0.02	33	5	24	4
Stn. 29	19333	2625	64	4	0.37	0.04	27	2	26	3
Stn. 30	14000	2828	147	12	0.07	0.01	20	1	23	7
Stn. 31	20000	1414	883	87	0.39	0.00	62	9	44	3
Stn. 32	14667	471	73	9	0.11	0.02	24	8	27	7
Stn. 65	11667	471	57	4	0.47	0.01	9	0	11	6
September 30										
Stn. 01	14000	1633	527	19	0.04	0.00	223	9	140	22
Stn. 12	21000	2160	92	7	0.20	0.00	32	1	27	0
Stn. 16	16000	816	840	128	0.54	0.05	67	2	46	3
Stn. 18	12333	943	150	16	0.42	0.02	61	7	48	4
Stn. 29	20000	816	303	54	0.49	0.05	190	36	75	12
Stn. 30	13333	1247	263	9	0.13	0.00	58	9	38	3
Stn. 31	22667	471	747	26	0.69	0.04	109	17	60	7
Stn. 32	19333	943	170	14	0.16	0.03	48	3	43	3
Stn. 65	15000	816	60	16	0.39	0.05	17	2	14	1

ULNr
(30,000 ug/g) FIGURE 3

CALCIUM IN SILVER MAPLE FOLIAGE

ACCL / GCCL Survey - 1987

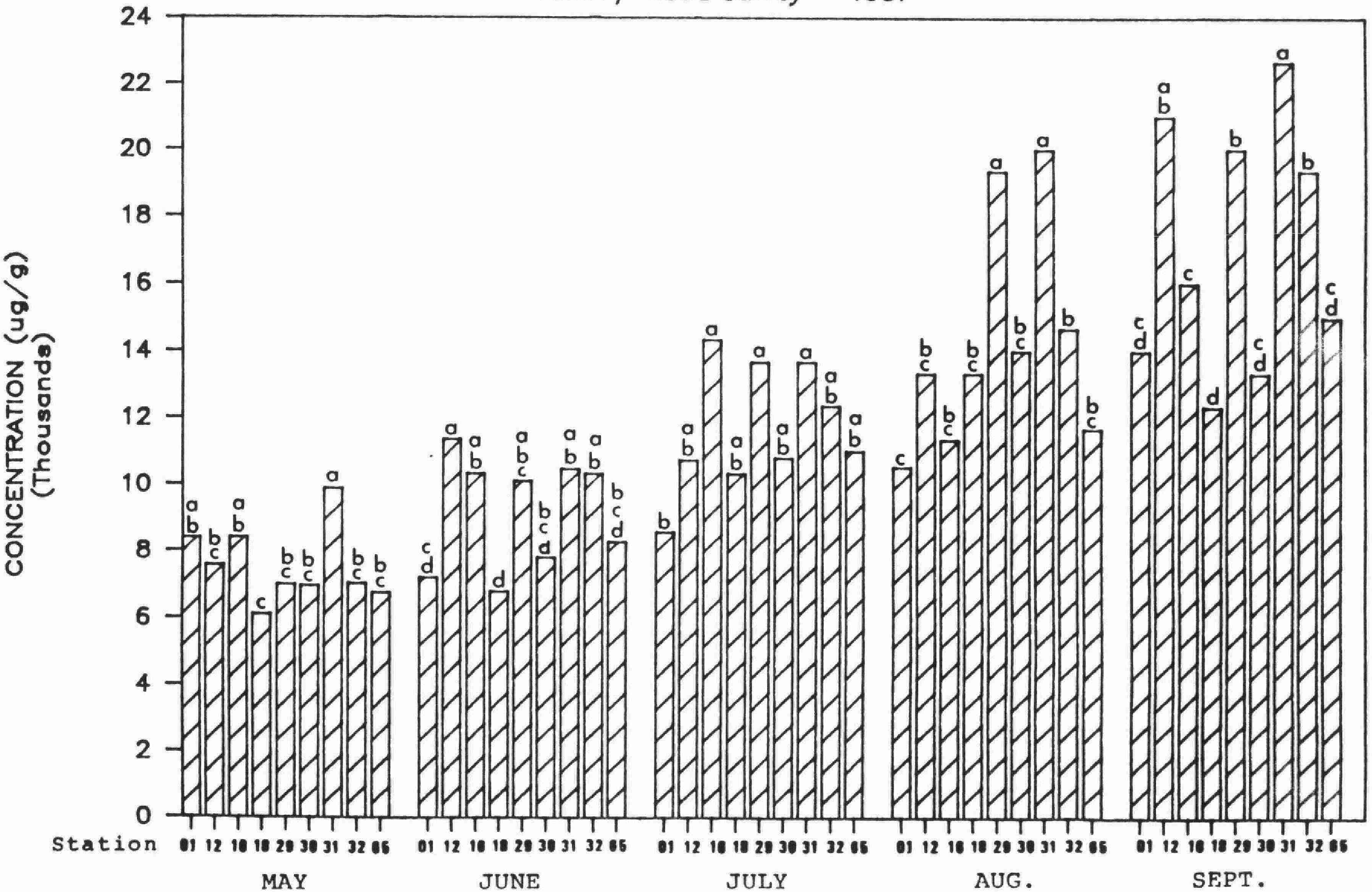


FIGURE 4

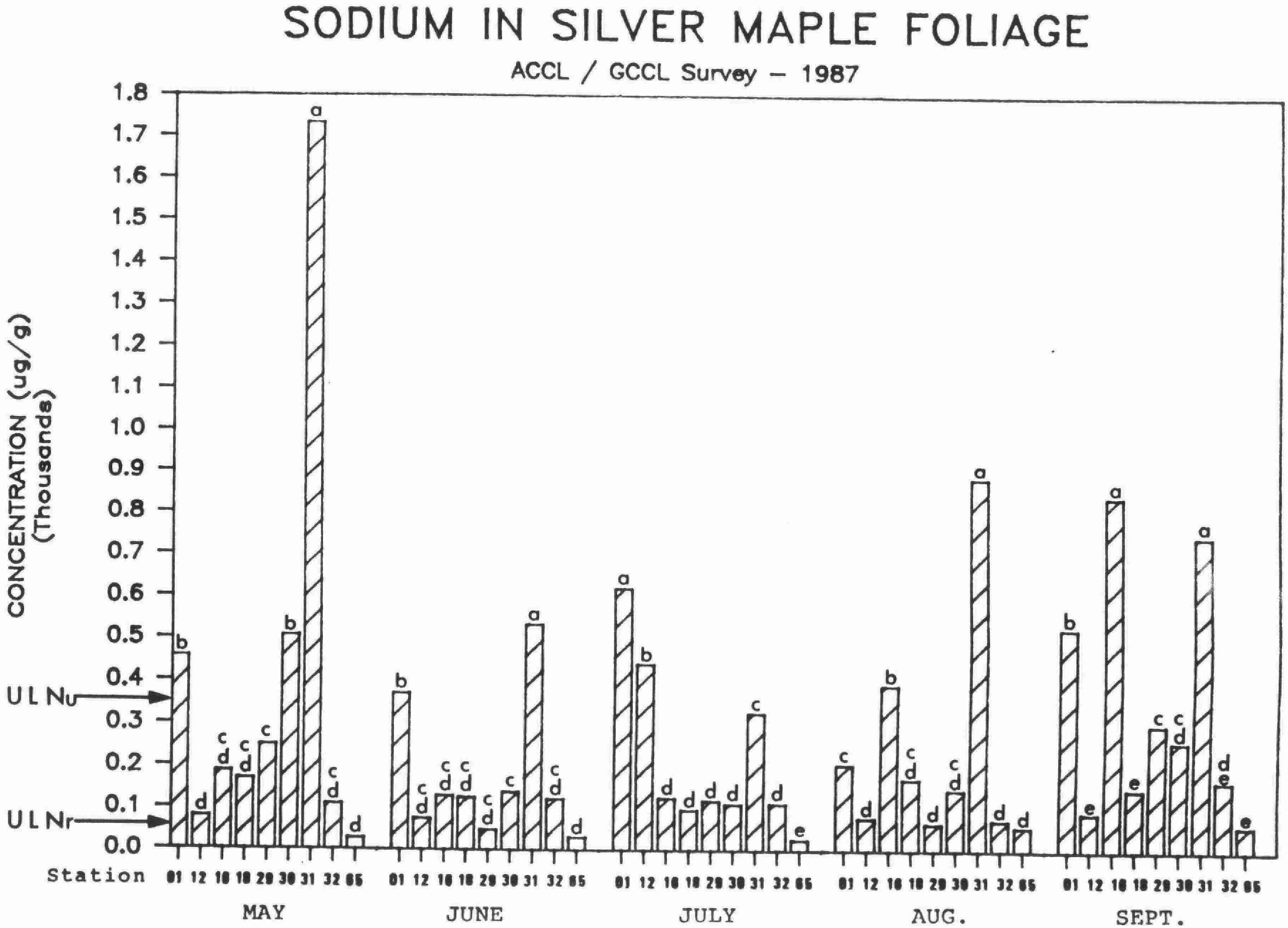
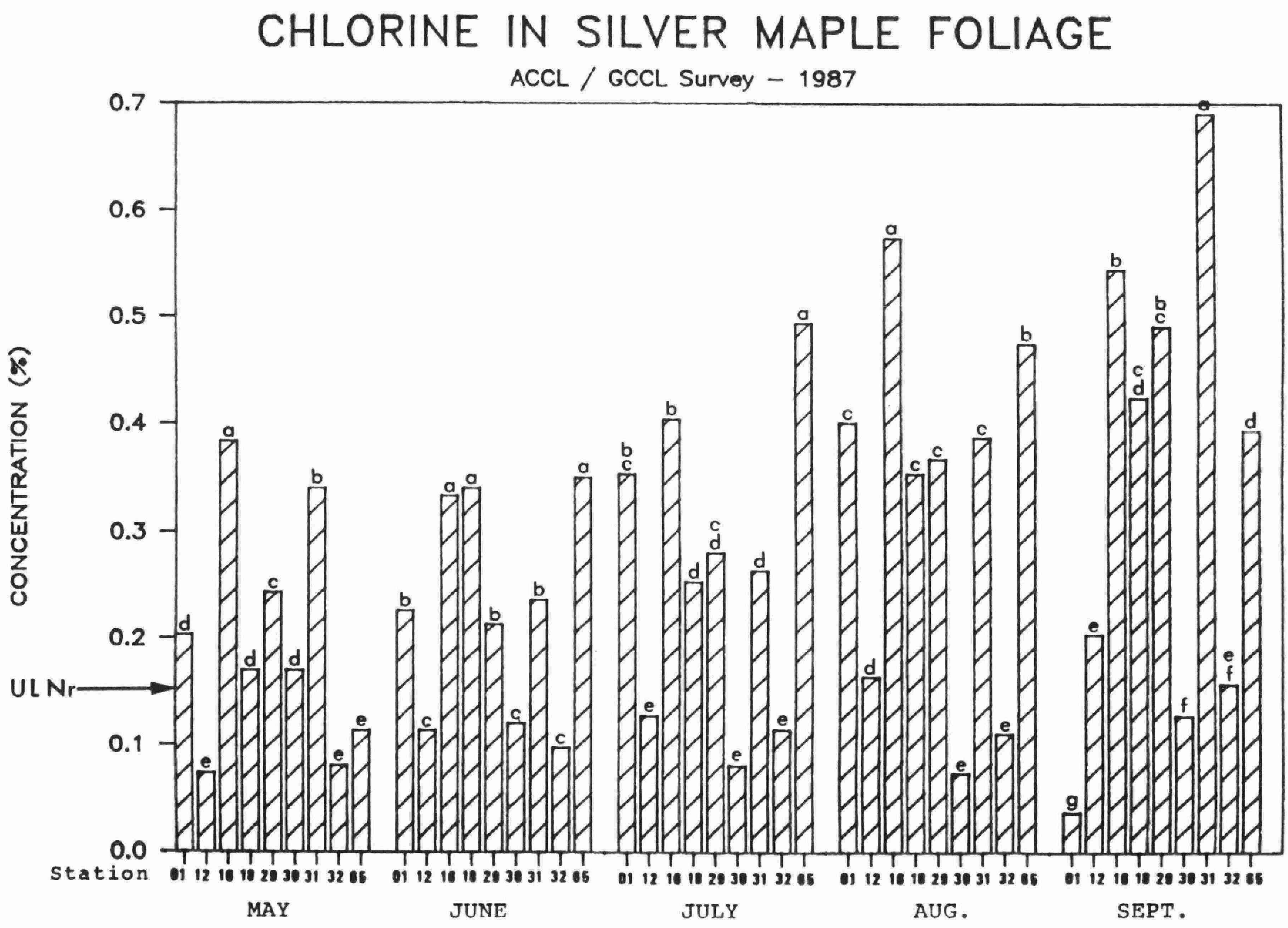

SODIUM IN SILVER MAPLE FOLIAGE
ACCL / GCCL Survey – 1987
CONCENTRATION (ug/g)
(Thousands)
ULNu
ULNr
Station
01 12 10 18 29 30 31 32 65
MAY
JUNE
JULY
AUG.
SEPT.

FIGURE 5



CHLORINE IN SILVER MAPLE FOLIAGE
ACCL / GCCL Survey - 1987
CONCENTRATION (%)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ULNr
Station
01 12 16 18 29 30 31 32 65
MAY
JUNE
JULY
AUG.
SEPT.

FIGURE 6

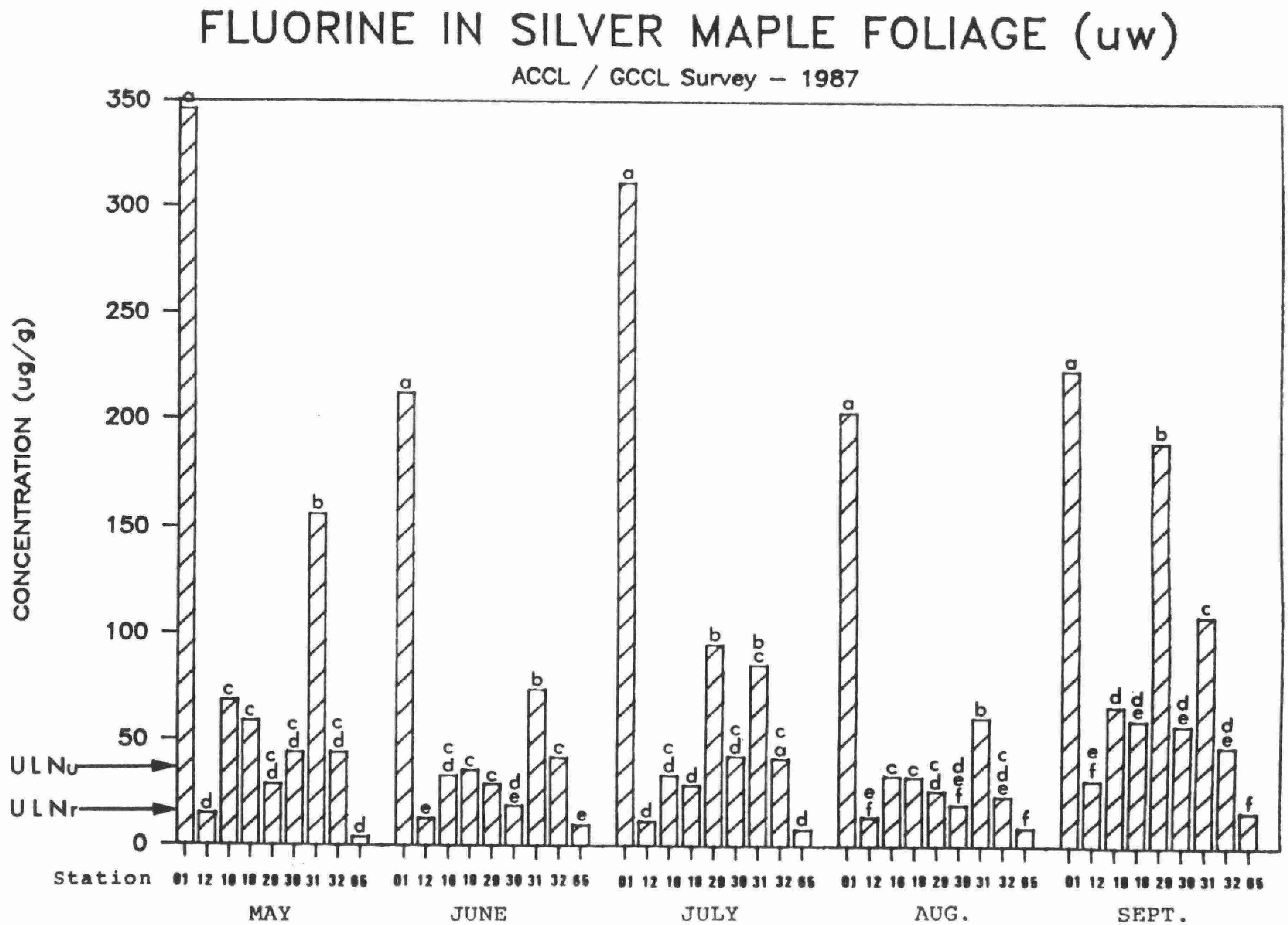
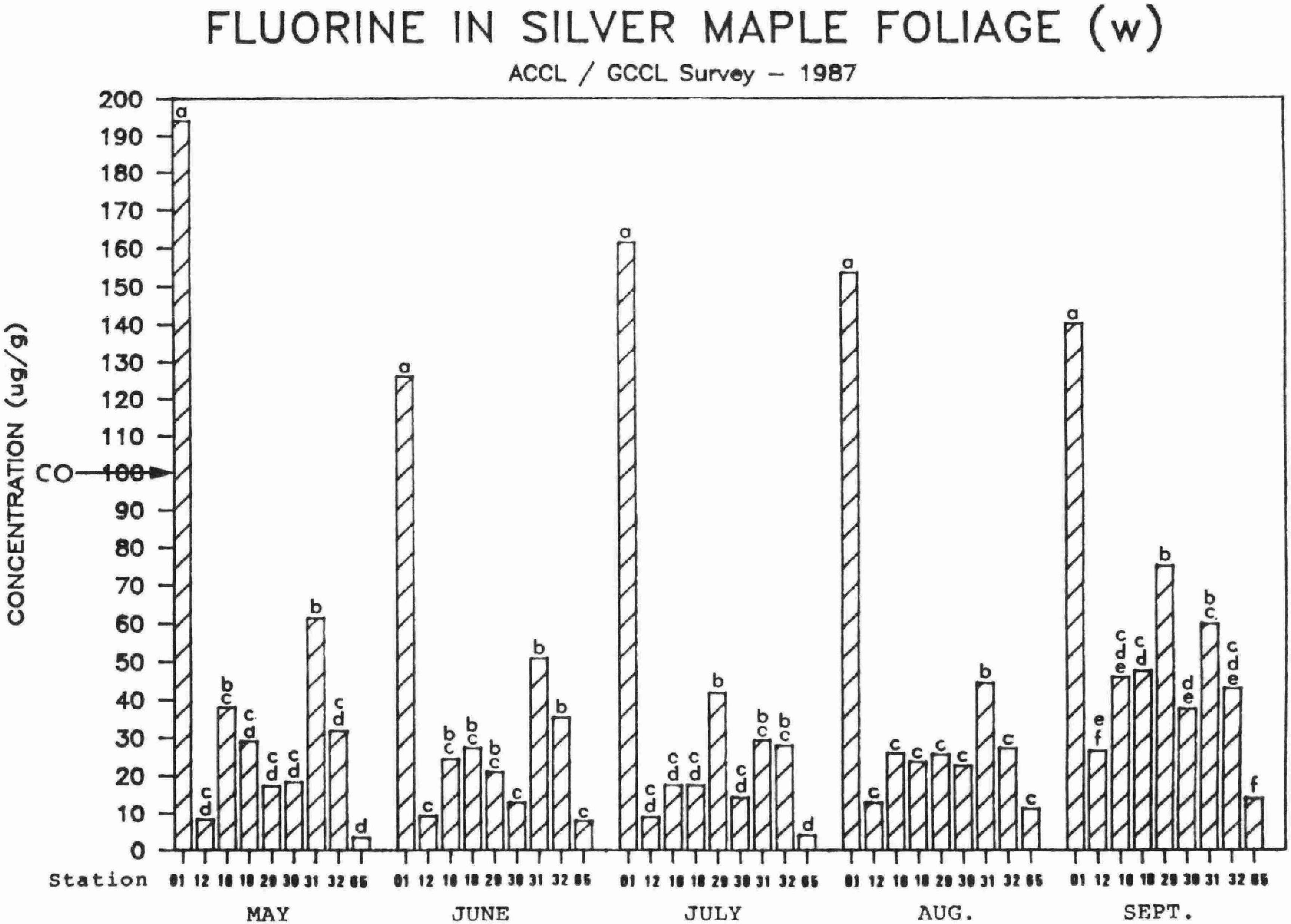

FLUORINE IN SILVER MAPLE FOLIAGE (uw)
ACCL / GCCL Survey - 1987
CONCENTRATION (ug/g)
350
300
250
200
150
100
50
0
ULNu
ULNr
Station
01 12 16 18 29 30 31 32 66
MAY
JUNE
JULY
AUG.
SEPT.

FIGURE 7


FLUORINE IN SILVER MAPLE FOLIAGE (w)
ACCL / GCCL Survey – 1987
CONCENTRATION (ug/g)
CO
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Station
MAY
JUNE
JULY
AUG.
SEPT.

4.2 Statistical Analysis

The Duncan's Multiple Range routine of SAS (1979) was used to determine if the concentrations of elements differed between the nine stations on each of the five sampling dates. Figures 3 through 7 contain alphabetic characters above each bar in the histogram distinguishing the Duncan groups. Bars with different characters indicate significantly different (p=0.05) concentration means for that sampling date.

To determine whether there were any relationships between the element concentrations in each sample, a series of linear regression analyses were performed using the regression analysis capabilities of Lotus 123 (Lotus 123, 1986). Table 3 is a matrix of correlation coefficients (r) for each pair (n = 135) of variables and indicators of the degree of significance.

Table 3:
Inter-Element Concentration Correlation Coefficients (r)

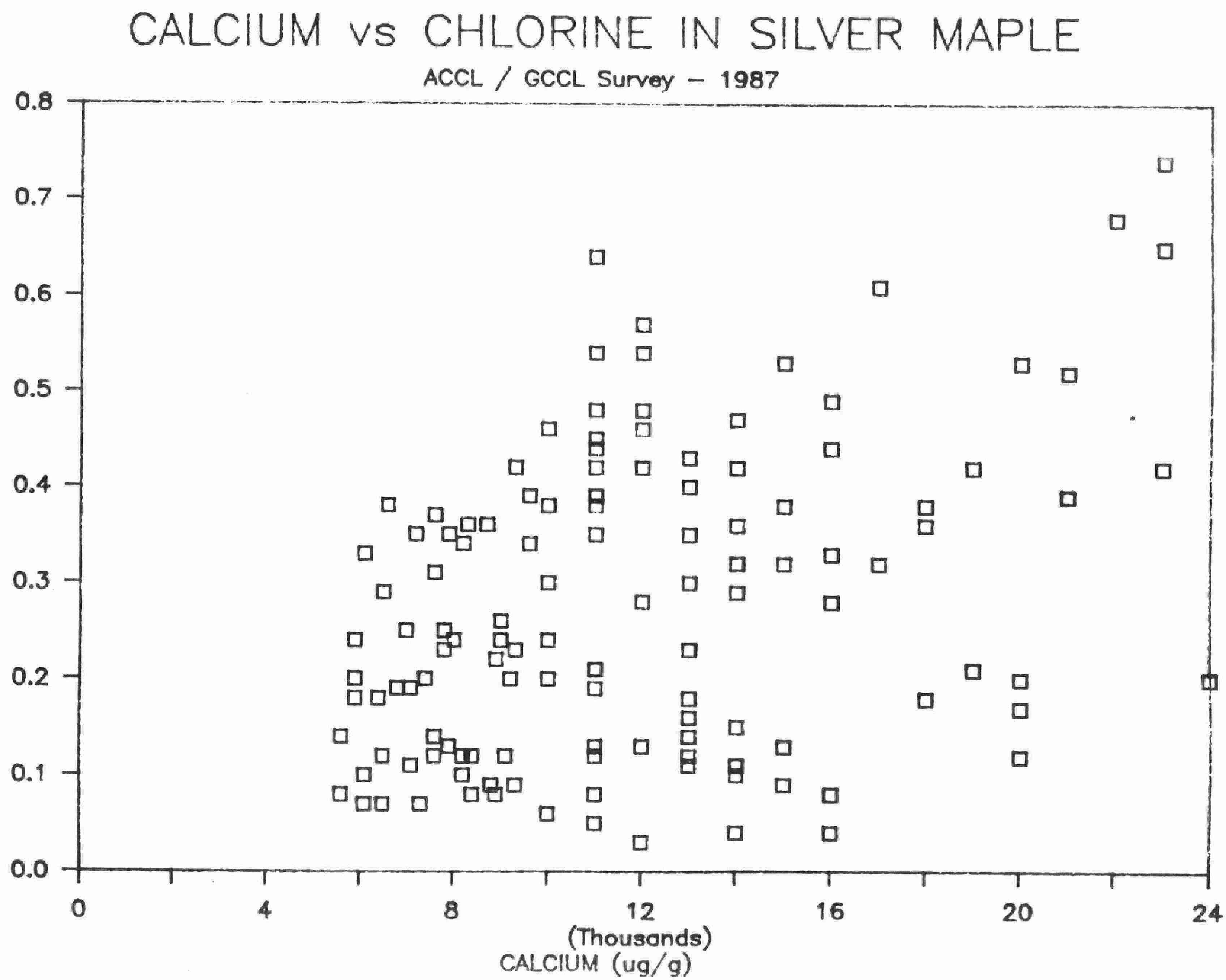
	Sodium	Chlorine	Fluorine (uw)	Fluorine (w)
Calcium	.126 ns	.351 **	.007 ns	.015 ns
Sodium		.270 **	.450 **	.363 **
Chlorine			.118 ns	.080 ns
Fluorine (uw)				.936 **

** = significant at p = .01
ns = not significant

Figures 8 through 12 are scatter plots of the individual sample analytical results for each pair of variables with a significant correlation. These plots are visual representations of the relationships between the different element concentrations in silver maple foliage samples.

The concentration means for each of the nine stations were also ranked in order of magnitude for each sampling date. A Rank Value of "1" indicates that that station had the highest concentration of a particular element on that collection date. By ranking data for each of the five sampling dates and then summing the Rank Values for each station, it is possible to assess which station(s) had the most consistent high or low concentrations of the different elements. The relative differences between these Rank Totals indicate the consistency with which a station had high or low element concentrations. The Rank Totals can range from five, for a station that had the highest concentration of an element on each sampling date, to 45, for a station that had the lowest concentration on each sampling date. The monthly Rank Values as well as the seasonal Rank Totals for each station are presented in Table 4.

FIGURE 8



CALCIUM vs CHLORINE IN SILVER MAPLE
ACCL / GCCL Survey – 1987
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
CHLORINE (%)
0
4
8
12
16
20
24
(Thousands)
CALCIUM (ug/g)

FIGURE 9

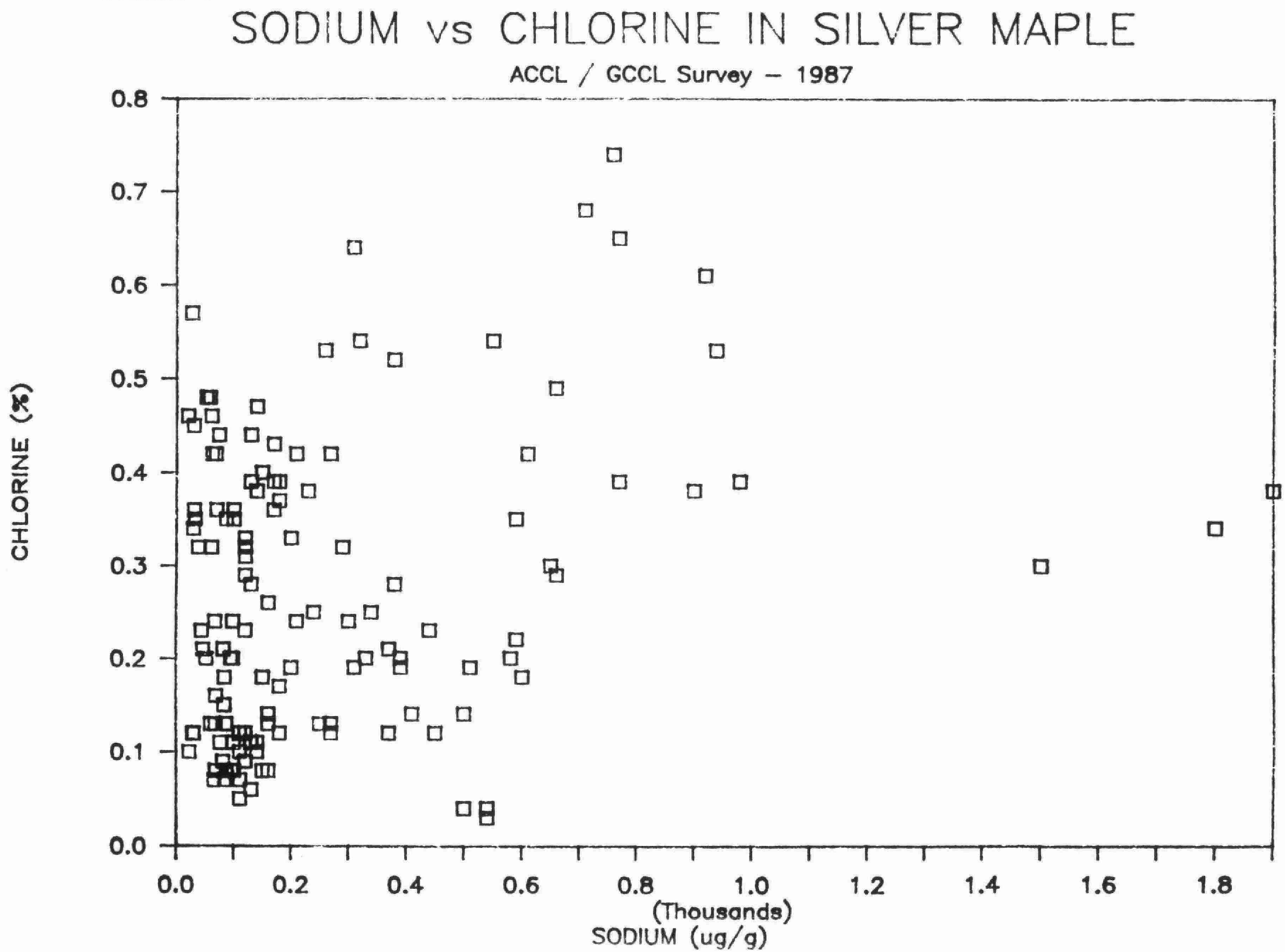

SODIUM vs CHLORINE IN SILVER MAPLE
ACCL / GCCL Survey - 1987
CHLORINE (%)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
(Thousands)
SODIUM (ug/g)

FIGURE 10

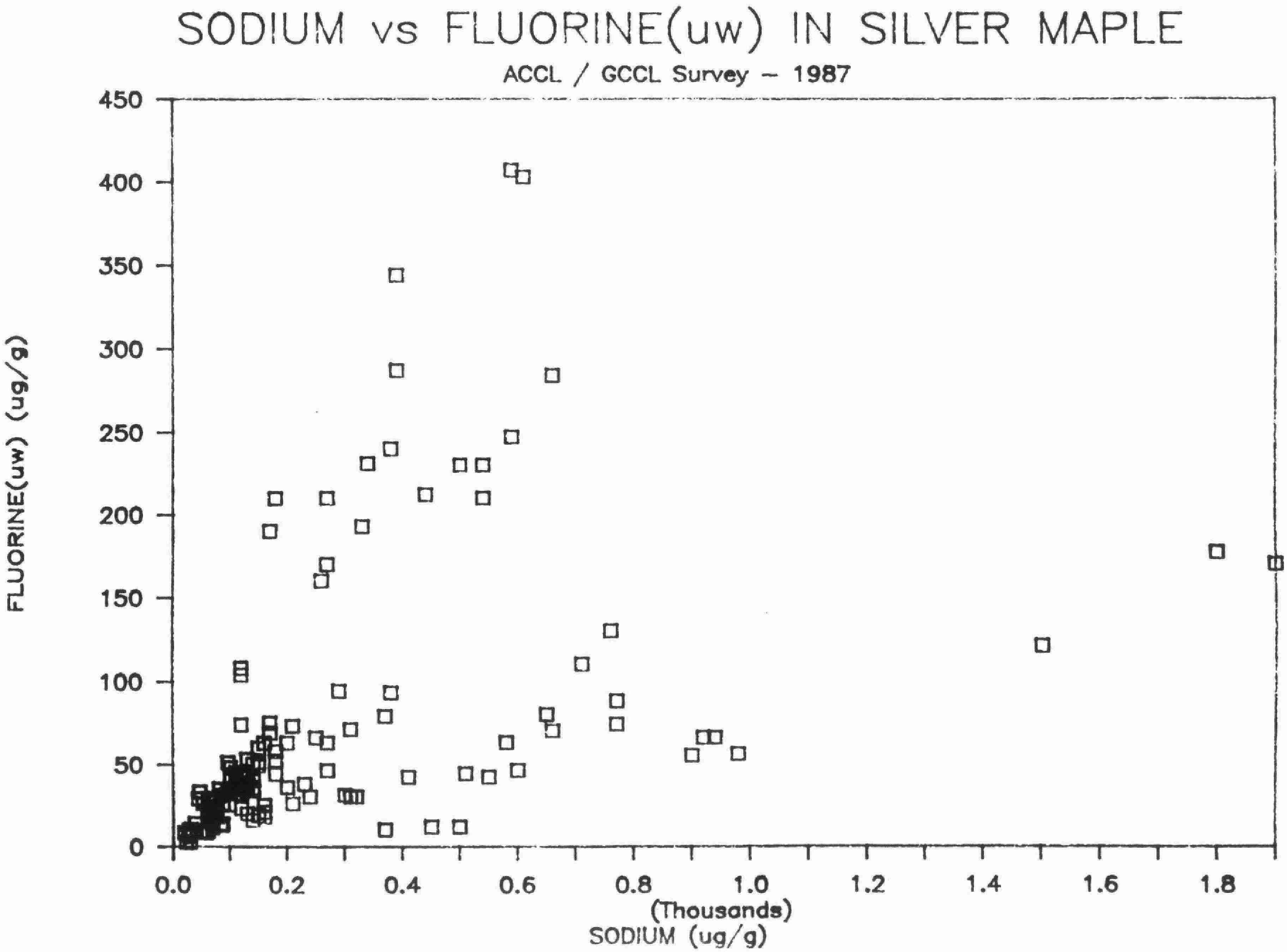

SODIUM vs FLUORINE(uw) IN SILVER MAPLE
ACCL / GCCL Survey – 1987
FLUORINE(uw) (ug/g)
0
50
100
150
200
250
300
350
400
450
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
(Thousands)
SODIUM (ug/g)

FIGURE 11

SODIUM vs FLUORINE(w) IN SILVER MAPLE

ACCL / GCCL Survey - 1987

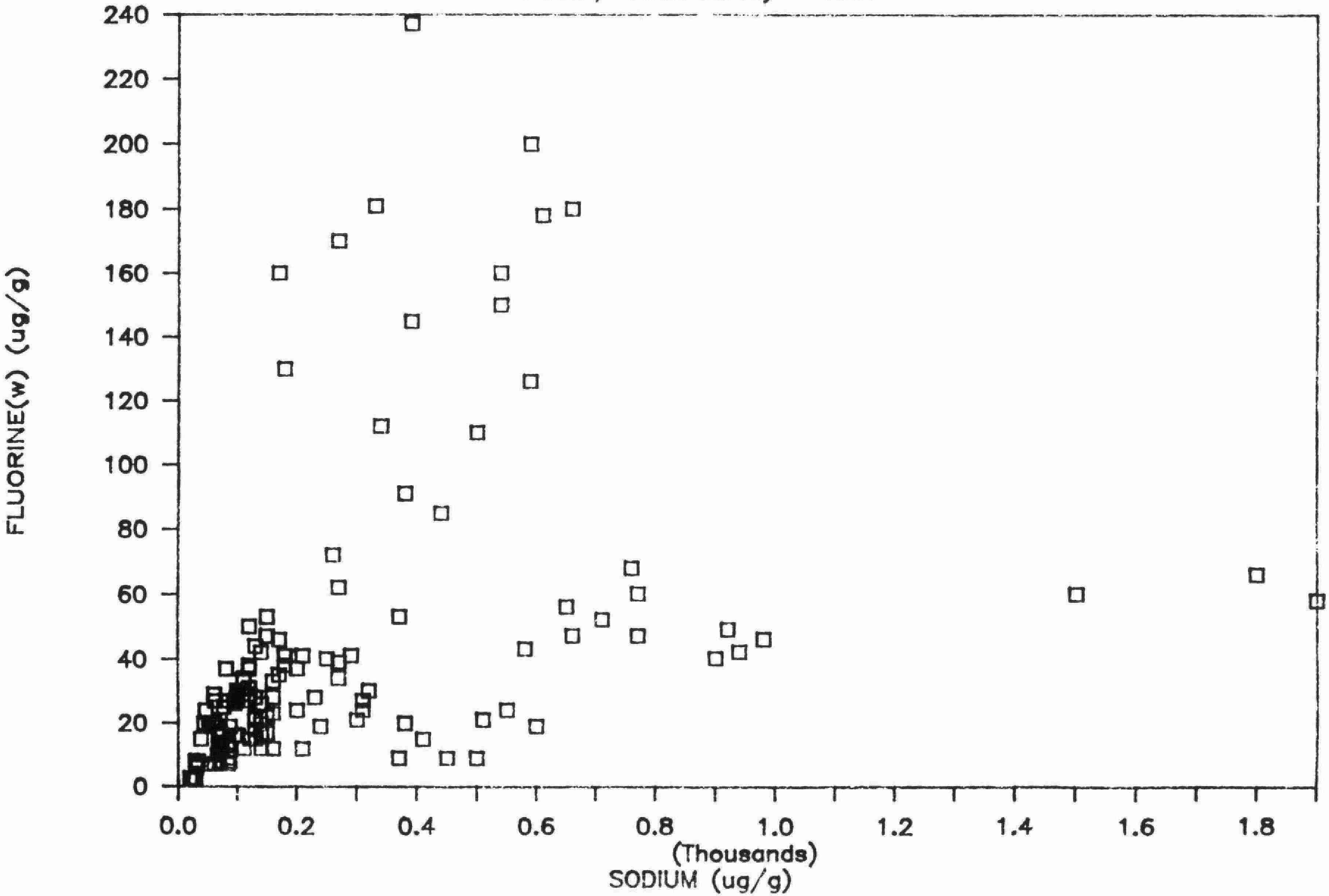


FIGURE 12

FLUORINE(uw) vs FLUORINE(w) IN SILVER MAPLE

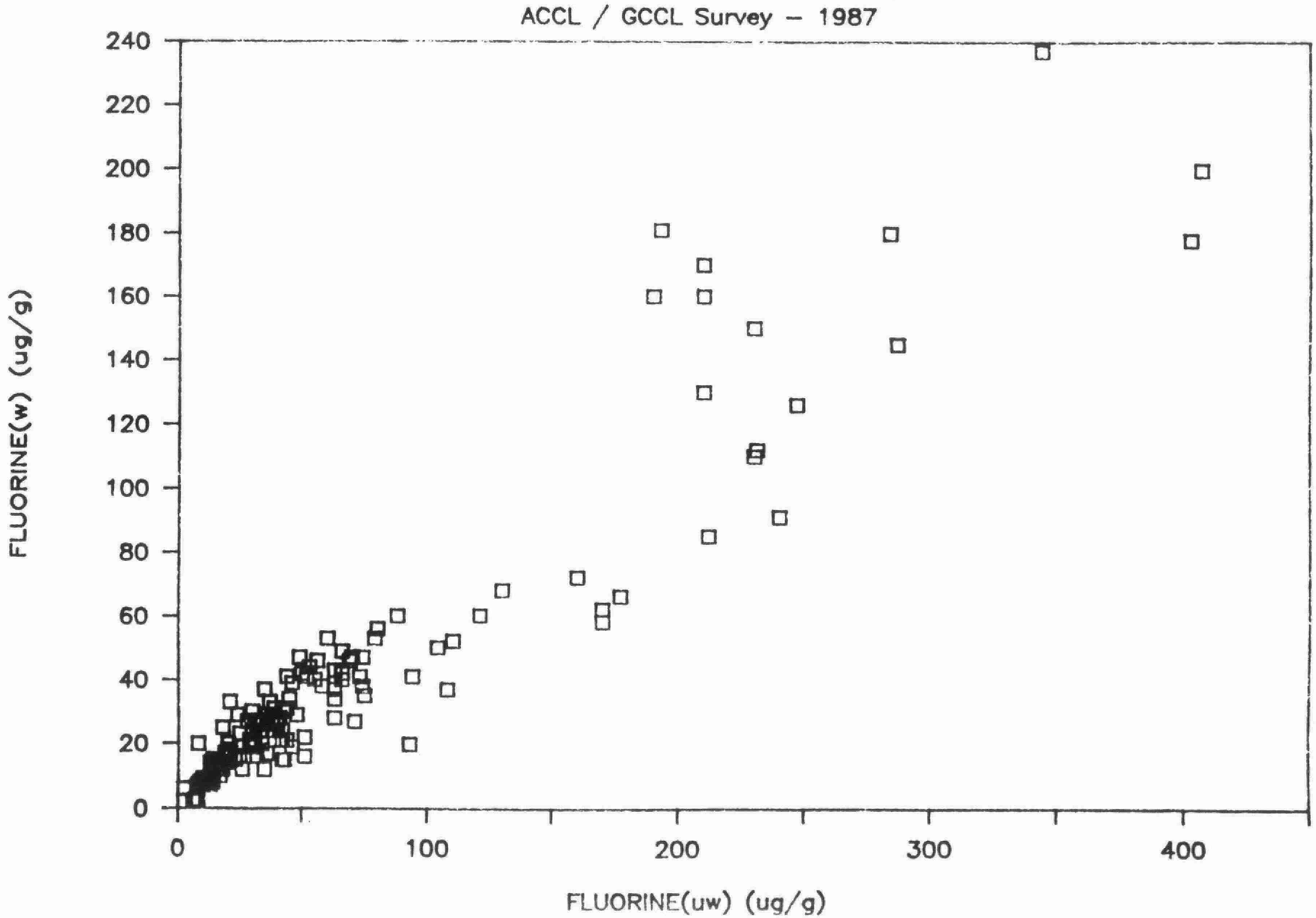


Table 4: Rank Values of Element Concentrations

		MAY	JUNE	JULY	AUG.	SEPT.	RANK TOTALS
CALCIUM	Stn. 01	3	8	9	9	7	36
	Stn. 12	4	1	7	5	2	19
	Stn. 16	2	3	1	8	5	19
	Stn. 18	9	9	8	6	9	41
	Stn. 29	6	5	3	2	3	19
	Stn. 30	7	7	6	4	8	32
	Stn. 31	1	2	2	1	1	7
	Stn. 32	5	4	4	3	4	20
	Stn. 65	8	6	5	7	6	32
SODIUM	Stn. 01	3	2	1	3	3	12
	Stn. 12	8	7	2	6	8	31
	Stn. 16	5	4	4	2	1	16
	Stn. 18	6	5	8	4	7	30
	Stn. 29	4	8	5	8	4	29
	Stn. 30	2	3	7	5	5	22
	Stn. 31	1	1	3	1	2	8
	Stn. 32	7	6	6	7	6	32
	Stn. 65	9	9	9	9	9	45
CHLORINE	Stn. 01	4	5	3	3	9	24
	Stn. 12	9	8	7	7	6	37
	Stn. 16	1	3	2	1	2	9
	Stn. 18	6	2	6	6	4	24
	Stn. 29	3	6	4	5	3	21
	Stn. 30	5	7	9	9	8	38
	Stn. 31	2	4	5	4	1	16
	Stn. 32	8	9	8	8	7	40
	Stn. 65	7	1	1	2	5	16
FLUORINE (uw)	Stn. 01	1	1	1	1	1	5
	Stn. 12	8	8	8	8	8	40
	Stn. 16	3	5	6	3	4	21
	Stn. 18	4	4	7	4	5	24
	Stn. 29	7	6	2	5	2	22
	Stn. 30	6	7	4	7	6	30
	Stn. 31	2	2	3	2	3	12
	Stn. 32	5	3	5	6	7	26
	Stn. 65	9	9	9	9	9	45
FLUORINE (w)	Stn. 01	1	1	1	1	1	5
	Stn. 12	8	8	8	8	8	40
	Stn. 16	3	5	5	4	5	22
	Stn. 18	5	4	6	6	4	25
	Stn. 29	7	6	2	5	2	22
	Stn. 30	6	7	7	7	7	34
	Stn. 31	2	2	3	2	3	12
	Stn. 32	4	3	4	3	6	20
	Stn. 65	9	9	9	9	9	45

4.3 Foliage Injury

The foliage on sample branches which were used for chemical analysis was visually rated for symptoms of injury symptomatic of fluoride or salt exposure. The injury symptoms, which were considered to be due to the fluoride or salt, consisted of a blackening of the tips of the palmately lobed silver maple leaves. Injury which could be ascribed to physiological disorders, diseases or insects was not considered in the ratings. Table 5 summarizes the severity of observed fluoride or salt injury symptoms.

Table 5: Injury Rating of Silver Maple Foliage

	May	June	July	Aug.	Sept.
Stn. 01	-	TR	TR-LT	TR	-
Stn. 12	-	-	-	-	-
Stn. 16	-	-	TR	TR	TR
Stn. 18	-	TR	-	-	-
Stn. 29	TR	TR	TR	TR	TR
Stn. 30	-	TR	-	-	-
Stn. 31	-	TR	TR	TR	LT
Stn. 32	-	TR	-	-	-
Stn. 65	-	-	-	-	-

- = not injured
TR = >0-1 % of foliage area injured
LT = 2-10 % of foliage area injured

5 Discussion

5.1 Calcium

Figure 3, Calcium in Silver Maple Foliage, revealed a definite trend of increasing foliar concentrations from the May to the September samples. The highest concentration mean encountered was 23,000 ug/g. This was considerably lower than the Upper Limit of Normal guideline for rural samples of 30,000 ug/g.

The seasonal trend of increasing calcium concentration can be ascribed to physiological causes, synonymous with maturation of foliage. Unpublished data produced by the author indicate similar seasonal trends in calcium concentrations in maple foliage from sites remote from industry or urbanization.

However, this trend was not completely consistent. Several instances of lower calcium concentrations in a subsequent sampling were encountered. These apparent inconsistencies can be attributed to the habit of maples to continue production of new foliage throughout the growing season and the probability of sampling different proportions of old and new leaves during each station visit.

The Duncan Multiple Range test identified up to four different concentration groups for any given sampling date. No one station had consistently highest or lowest concentrations for all sampling dates. Station 31 did have a notably low Rank Total of seven, identifying it as the station with relatively high concentrations of calcium in the foliage. However, neighbouring Station 1 with a Rank Total of 36 had the second lowest concentrations. Both stations were downwind of the industrial complex.

Compounds containing calcium are used and produced at the industrial complex. Releases of these compounds, specifically calcium carbonate, do occur during the loading of the

lime kilns operated by GCCL (Russell, 1988). These releases are not reported to the Ministry by the company, apparently because they occur with such regularity that they are considered part of the normal operating conditions at the plant.

These acknowledged releases did not manifest in identifiable foliar concentration elevations. This is probably a result of a combination of high background concentrations of calcium in foliage, limited foliar absorption and rain-induced foliar washing of the calcium dusts.

It is unlikely that foliar injury by calcium will be induced due to its low toxicity. The use of silver maple foliage as a monitor of fugitive calcium dust exposure in the ACCL/GCCL survey area should be reconsidered.

The most probable long term environmental effect of these releases would be the increase of soil pH if the emissions are in the form of alkaline calcium compounds. The significance of this potential effect as well as the effects of chronic exposure of perennial vegetation by these alkaline dusts has not been determined.

5.2 Sodium

The most significant observations regarding the concentrations of sodium in silver maple foliage (Figure 4) were the extremely wide range in the concentrations encountered during this survey and the frequency and magnitude with which these concentrations exceeded the Upper Limit of Normal guidelines. Excluding the control Station 65 and the relatively remote Station 12, the concentration means ranged from 47 ug/g for Station 29 in June to 1733 ug/g for Station 31 in May. The rural ULN guideline of 50 ug/g was exceeded on 41 out of the possible 45 (5 sampling dates x 9 stations) occasions. Of the remaining four, three were for samples collected at the control Station 65. The urban ULN guideline of 350 ug/g was exceeded on 12 of the possible 45 occasions.

Residual salt in soil from road deicing operations can be a source of sodium in foliage; however, the pattern of sodium contamination of sampled trees in the ACCL/GCCL survey area does not implicate road salt as a major source of foliar contamination.

The Duncan Multiple Range test identified Station 31 as having concentrations in the highest group on four of the five sampling dates. The control Station 65 concentrations were assigned to the group with the lowest means on all sampling dates. The mean ranking procedure confirmed these trends, producing a Rank Total of eight for Station 31 and a Rank Total of 45 for Station 65. It also identified Stations 1 and 16, with Rank Totals of 12 and 16 respectively, as additional stations with consistently high concentrations of sodium in the foliage.

The wide variation along with notably higher sodium concentrations at selected stations suggest episodic releases of sodium compounds. The elevated concentrations at Stations 1 and 31 are consistent with the prevailing southwesterly winds (Figure 2) transporting sodium emitted from the industrial complex toward these stations. However, Station 16 is upwind of the prevailing direction, but relatively close to the sodium operations of GCCL (Figure 1). Closer examination of Figure 4 reveals that sodium at Station 16 was notably higher in August and especially in September than during the first three sampling dates. This supports the hypothesis that sodium releases are episodic, with these August and September increases probably due to releases during periods of northerly winds.

An additional suggestion of episodic and in this case significant releases of sodium is contained in the exceptionally elevated concentration of sodium encountered at Station 31 during the May sampling. The concentration mean encountered was 1733 ug/g, approximately twice as high as

any other such observation at this station, which had the most consistently high sodium concentrations. It should be noted that the analytical results for all three May/Station 31 replicate samples were consistent. Two adjacent stations, Station 1 to the east and Station 30 to the west, also had highly elevated sodium concentrations, 457 ug/g and 507 ug/g, respectively, on this sampling date. These observations suggests a major release of sodium prior to the May 28 sampling date which primarily impacted Station 31, and to a lesser extent, the adjacent stations. Subsequent samples from Station 31 had much lower concentrations, indicating washing of foliar surface deposits, leaching of foliar absorbed sodium by rain, or a combination of the two processes. Another possibility for the subsequent reduction in sodium concentrations at this station is the growth of new unexposed foliage and the concomitant dilution effect.

Whether such a release did occur is not known since no notice of such an occurrence was received by the Phytotoxicology Section or by the Windsor District Office (Gibson, 1988).

The evidence for episodic emissions of sodium compounds does not preclude the probability of chronic lower level emissions of sodium. It should be recalled that the concentrations encountered frequently exceeded the ULN guidelines. The sodium release episodes, however, are the dominant factor in the excessive contamination of silver maple, and in all probability, other foliage.

Possible contributions of sodium from the operations of Canada Occidental Petroleum are indicated as elevated foliar sodium concentrations at Stations 12 and 65. The later is considered a control station for the ACCL/GCCL survey. Concentrations at these stations commonly approached or exceeded the rural ULN guideline of 50 ug/g. On one occasion, Station 12 in July, the concentration exceeded the urban ULN

guideline of 350 ug/g. Station 12 is the closest station to this company and sodium releases from the shipping and receiving operations could impact on this station during periods of northwesterly winds.

5.3 Chlorine

Concentrations of chlorine in silver maple (Figure 5) are also characterized by an extremely wide range and a large number of occurrences, 32 of a possible 45, where the concentration exceeded the rural Upper Limit of Normal guideline of 0.15%. There is no urban ULN guideline.

Chlorine contamination can occur as a result of road deicing operations. However, as was the case for sodium, the pattern of chlorine contamination of the sampled trees does not implicate road salt as a major source of foliar chlorine.

The Duncan Multiple Range test failed to identify any one station with chlorine concentrations falling consistently into either the highest or lowest concentration group. Station 16 concentrations were in the high group on three occasions. Station 32 concentrations were in the low group on four occasions and Stations 12 and 30 concentrations were in the low group on three occasions each. Meanwhile, the control Station 65 concentrations were in the high group twice and the low group once. The mean concentration ranking procedure identified Station 16 as having the most consistently high chlorine concentrations with a Rank Total of nine; followed by Stations 31 and 65, both with a Rank Total of 16. Stations 32, 30 and 12 had the lowest Rank Totals, 40, 38 and 37 respectively.

The results of these analyses indicate that no clear pattern of chlorine contamination of silver maple foliage exists. Downwind stations frequently had the lowest chlorine concentrations. Meanwhile, the control Station 65 had the highest chlorine concentrations on two of the five sampling

dates. Since the ULN guideline was exceeded so frequently, a source of chlorine is indicated. The pattern of foliar chlorine concentrations, or lack thereof, fails to suggest where this source is located. Any attempt to explain this complex pattern would be speculative.

It should be recalled that both ACCL and GCCL use and manufacture compounds containing chlorine. In addition, a separate and probably significant source of chlorine exists in Amherstburg, namely Canada Occidental Petroleum Ltd. Emissions from this source consist of sodium chloride and sodium chlorate particulates and chlorine gas (Luyt, 1986). Since the sodium compounds are in particulate form and are released at ground level, their zone of influence would be restricted to the source area. The chlorine gas, however, would have a much wider zone of influence. This chlorine may very well be a significant contaminant of vegetation in the general Amherstburg area. It is not possible to assign relative contributions of chlorine to the environment to the three potential sources with the current survey design.

A relatively weak but still noticeable trend does exist in foliar chlorine concentrations. This trend is visible in Figure 5 as a tendency towards higher chlorine concentrations with later sampling dates. A similar trend was seen in the calcium data which was ascribed to physiological causes. In the case of chlorine, physiological causes, if any, are likely secondary due to the exceptionally high concentrations, exceeding the ULN guideline, and the wide range of concentrations during any sampling date. The trend suggests accumulation of atmospheric chlorine by the foliage with the variation due to inconsistent age of the sampled foliage and imbalances in rates of accumulation or loses by the foliage.

5.4 Fluorine

The concentrations of fluorine in unwashed and washed silver maple foliage are represented in Figures 6 and 7,

respectively. The rural ULN guideline of 15 ug/g for unwashed foliage was met or exceeded on every occasion except on four of the five sample collections at control Station 65 and three of the five sample collections at Station 12. Station 12 is upwind of the ACCL HF plant and is the most remote (excluding the control) station from the HF plant. The urban ULN guideline of 35 ug/g was exceeded on 24 of the possible 45 occasions. Exceedences occurred at all stations except Stations 65 and 12.

Fluorine concentration in washed silver maple foliage was one of the limits set forth in the 1978 Control Order. The limit of 100 ug/g was exceeded at Station 1 on each sampling date. The highest concentration (194 ug/g in May) was almost twice the former Control Order limit. All remaining stations fell below this limit. To confirm the validity of these exceptionally high concentrations, a silver maple tree approximately 30 metres from Station 1 was sampled in September. This single sample was determined to contain 240 and 170 ug/g fluorine based on unwashed and washed subsamples respectively. These values are consistent with the triplicate means of 223 and 140 ug/g, unwashed and washed respectively, determined for Station 1 in September.

The Duncan Multiple Range test on unwashed foliage fluorine data placed all samples from Station 1 into the highest concentration group on each sampling date. This group contained only Station 1 samples. This test further identified Station 31 as the station with concentrations in the second highest group on four of the five sampling dates. Stations 12 and 65 were consistently placed into the lowest concentration group. This test produced very similar groupings for the washed foliage fluorine data. The only difference was the placement of Station 31 in the second highest group on all occasions. The ranking procedures simply

confirmed Stations 1 and 31 with the highest and Stations 65 and 12 with the lowest concentrations of fluorine in both washed and unwashed foliage.

This analysis clearly identifies the ACCL/GCCL complex as a source of significant contamination of silver maple by fluorine. The most proximal and downwind stations have the highest concentrations of fluorine, while the most remote and upwind stations have the lowest concentrations. The only industrial sources of fluorine in the Amherstburg area are associated with the operations of ACCL. However, the Phytotoxicology Section did not receive reports of unusual releases of this contaminant.

Upon excluding the high (1 and 31) and low (12 and 65) stations, fluorine concentrations in unwashed foliage at the remaining stations were in a relatively narrow range of from 19 to 95 ug/g with the exception of Station 29 in September. Chronic emissions of fluorine together with acute episodes which induce increases in foliar fluorine concentrations at specific stations over the course of the sampling period are indicated.

5.5 Inter-Element Relationships

Table 3, a correlation matrix between the foliar elements, reveals five pairs of elements with significant correlations. Ranked in order of the correlation coefficient (r), these pairs include:

1. Fluorine (uw) vs. Fluorine (w)
2. Sodium vs. Fluorine (uw)
3. Sodium vs. Fluorine (w)
4. Calcium vs. Chlorine
5. Sodium vs. Chlorine

Figures 8 through 12 are scatter plots of the individual sample concentrations for each of the significantly correlated pairs of elements. With the exception of the relationship depicted in Figure 8, a plot of the unwashed versus washed foliage fluorine concentrations, the correlation coefficients between the elements are not high ($r<0.5$), nor do the plots indicate strong relationships. However, due to the large number of samples ($n = 135$), these correlations are statistically significant.

When the samples containing the unusually high sodium concentrations are removed (Station 31 in May), the correlation coefficients between sodium and both forms of fluorine improve. However, the correlation coefficient between sodium and chlorine does not. This later observation is indicative of the independence of sodium and chlorine emissions. These emissions are either not exclusively sodium chloride or there is an independent source of one of the elements, such as chlorine from Canada Occidental Petroleum, or a combination of these conditions.

The strong correlation between the fluorine concentrations in unwashed and washed foliage is not in itself a significant observation. If the source of fluorine was the soil, laboratory washing would leach a proportion of the fluorine and the correlation would remain strong. What is

significant in this analysis are the large differences in concentrations between the two sample types. Laboratory washing removed an average (all stations and dates) of 40 percent of the fluorine. This suggests atmospheric sources of fluorine deposited to the foliage, with a substantial portion of the fluorine removable by washing.

The significant correlation of sodium with both forms of fluorine are indicative of common sources for these contaminants. However, since these elements are not involved in any common industrial processes, their emissions must be independent. Since the correlations are relatively poor, it is probable that emissions are not continuous, but consist of intermittent, acute releases. The points of impingement are dependent on the prevailing winds during these emission episodes. Such releases of sodium were hypothesized in the discussion of the exceptionally high sodium concentrations encountered at Station 31 in May.

Releases of fluorine may also consist of acute episodes as may occur during production upsets. However, since fluorine concentrations at any given station had a tendency to maintain their high, intermediate or low rank characteristics throughout the sampling period, chronic emissions are indicated as a significant cause of the elevated levels.

The significance of the calcium versus chlorine correlation might also suggest common sources. However, calcium concentration patterns were ascribed mainly to physiological causes. Furthermore, the independent source of chlorine in the area precludes ascribing all chlorine contamination to the ACCL/GCCL complex. The reason for the significance of the correlation is probably due to common trends of increasing concentrations of both elements with progressively later sampling dates. In the case of chlorine, bioaccumulation in the foliage is indicated.

The weakest of the statistically significant correlations is between sodium and chlorine. However, the second source of chlorine together with increasing and decreasing chlorine concentrations at a given station between sampling dates makes it difficult to implicate salt (NaCl) as the sole form of either sodium or chlorine emissions. Some of the industrial processes, discussed in the Introduction, use salt as a raw material. In addition, various sodium and chlorine compounds are used or produced. Consequently, sodium and chlorine could be emitted in a variety of compounds, including NaCl.

5.6 Foliage Injury

Rating foliar injury is a subjective procedure and the results of such ratings must be interpreted with caution. In this survey the sample branches were the basis of the ratings and therefore the ratings do not apply to the whole of the tree constituting the sample station. There is a possibility that due to chance, a set of sample branches may have contained injury symptoms on one sampling date but a set of branches from the same station taken on a subsequent date did not have the symptoms. Consequently, the analysis of injury ratings, as contained in Table 5, must be restricted to an analysis of trends which could identify stations which were recorded as containing foliar injury most consistently.

It must also be noted that since the sample trees are of variable age, occur in different habitats and are genetically different, their susceptibility to injury due to fluorides and salt would not be identical. Furthermore, injury symptomatology caused by exposure to these two types of contaminants is very similar, consisting of marginal necrosis.

The injury ratings as recorded in Table 5 are generally in the 'trace' category. This indicates that the extent of injury was less than two per cent of the foliage area. On two occasions the degree of injury was slightly greater. Stations 12 and 65 were recorded to be free of injury due to airborne contaminants at all observation times. Station 29 exhibited injury on all five occasions. Stations 1, 16 and 31 exhibited injury on either three or four occasions. The remaining stations were recorded as injured on one occasion each.

Bernstein (1980) notes that if sodium or chlorine foliar concentrations exceed 0.2 or 0.5 percent, respectively, in fruit trees, then injury can usually be attributed to these contaminants. Assuming that silver maple has similar tolerances, it should be noted that sodium concentrations encountered during this survey were, with one exception, less than 1000 ug/g (0.1%). Chlorine concentrations did approach or exceed the 0.5% level on several occasions, but it should be noted that one sampling station that had typically high chlorine concentrations was the control station and no injury was reported.

NAS (1971) suggests that susceptible plants exhibit injury symptoms when foliar fluorine concentrations are in the range of 20 to 150 ug/g. Resistant plants can tolerate fluorine concentrations of 4000 ug/g without visible injury. Silver maple is considered to have intermediate sensitivity to fluorides.

In this survey the highest fluorine concentrations were reported at Station 1 in May, yet the foliage was injury free. Station 29 was reported to contain injured foliage on each sampling date while fluorine concentrations in unwashed foliage ranged from 27 to 190 ug/g. There is a lack of a clear relationship between injury and fluorine concentrations.

Consequently, it is not possible to definitively ascribe the marginal necrosis injuries observed to either fluorides or the sodium or chloride components of salt. Differences in susceptibility between individual trees as well as the possibility of synergistic interaction effects of the contaminants may, in part, account for this.

6 Private Property Alleged Injury Investigations

In 1987, the Phytotoxicology Section received requests for investigations of vegetation injury from eleven property owners in the vicinity of the ACCL/GCCL complex. All of these requests concerned properties on Texas Road which is an east-west road immediately adjacent to and north of the industrial complex. The investigations on six of the properties revealed a variety of insect, disease and physiological causes for the injuries. Injury due to air pollutants could not be identified on these six properties.

The remaining five properties were all adjacent to each other and backed onto the ACCL/GCCL complex boundary in the immediate vicinity of the hydrofluoric acid and sodium carbonate and calcium chloride plants. The vegetation on these properties consisted of a large number and variety of fruit and ornamental trees. Foliar injury on these plants consisted of varying degrees of marginal necrosis.

Four of these investigation requests were forwarded to the Phytotoxicology Section by GCCL personnel on June 29, 1987. GCCL had received complaints of vegetation injury from these property owners on June 1, 1987. The complaints were precipitated by an accidental release of ammonia by GCCL on May 29, 1987, the odour of which could be detected by the property owners. This release was confirmed verbally by GCCL personnel. The fifth investigation request was received by Phytotoxicology investigators on June 29, 1987, during investigations of the four original requests.

These investigations concluded that the foliar injury to fruit and ornamental trees was due to fluoride or salt exposure. There was no evidence of injury caused by ammonia vapour.

A second ammonia release by GCCL occurred on July 31, 1987. No allegations of vegetation injury on private property were received by the Phytotoxicology Section as a consequence of this release. According to the GCCL letter to the Ministry acknowledging this release, the wind at the time was easterly and therefore the released ammonia would not impact on private properties.

Since no other abnormal releases of other materials by either ACCL or GCCL were reported to the Phytotoxicology Section, it must be concluded that the injuries on the five properties were the result of previous acute or chronic emissions of fluorides and salt. The first ammonia release and associated odour may have been a catalyst for the property owners to examine their trees and request the investigations.

7 Review of Historic Silver Maple Foliage Chemistry Data

As discussed in the Introduction, the Phytotoxicology Section has been conducting vegetation surveys in the vicinity of the ACCL/GCCL complex since 1970. These surveys have traditionally included silver maple foliage injury rating and sampling for chemical analysis. The current configuration of sampling stations was established in 1975. Prior to 1975, the survey consisted of stations along three radii extending from the industrial complex. Six of the nine 1987 stations have been sampled consistently since 1975 at the end of each month during the growing season. These stations (numbers 1, 16, 18, 29, 30, and 31) are the most proximal to the complex and are located along Texas Road to the north and in a residential area to the south of the complex (Figure 1). A list of Phytotoxicology Section reports on these annual surveys is given in Appendix A.

The chemical analysis of these historic samples have usually included the same elements as determined in the 1987 survey. In some years, however, a particular element either was not analyzed (eg. calcium in 1975), was not reported in that year's report or subsequent reports (eg. sodium in 1978), or the element was determined on samples which were washed when more recent surveys did not include washing (eg. chlorine in 1975). These historic data as well as the 1987 data have been compiled in Appendix B. Also included are available historic data for other stations active in 1987 (Stations 12, 32 and 65), to serve as an up to date data base for time trend analyses should this survey be continued and include these stations.

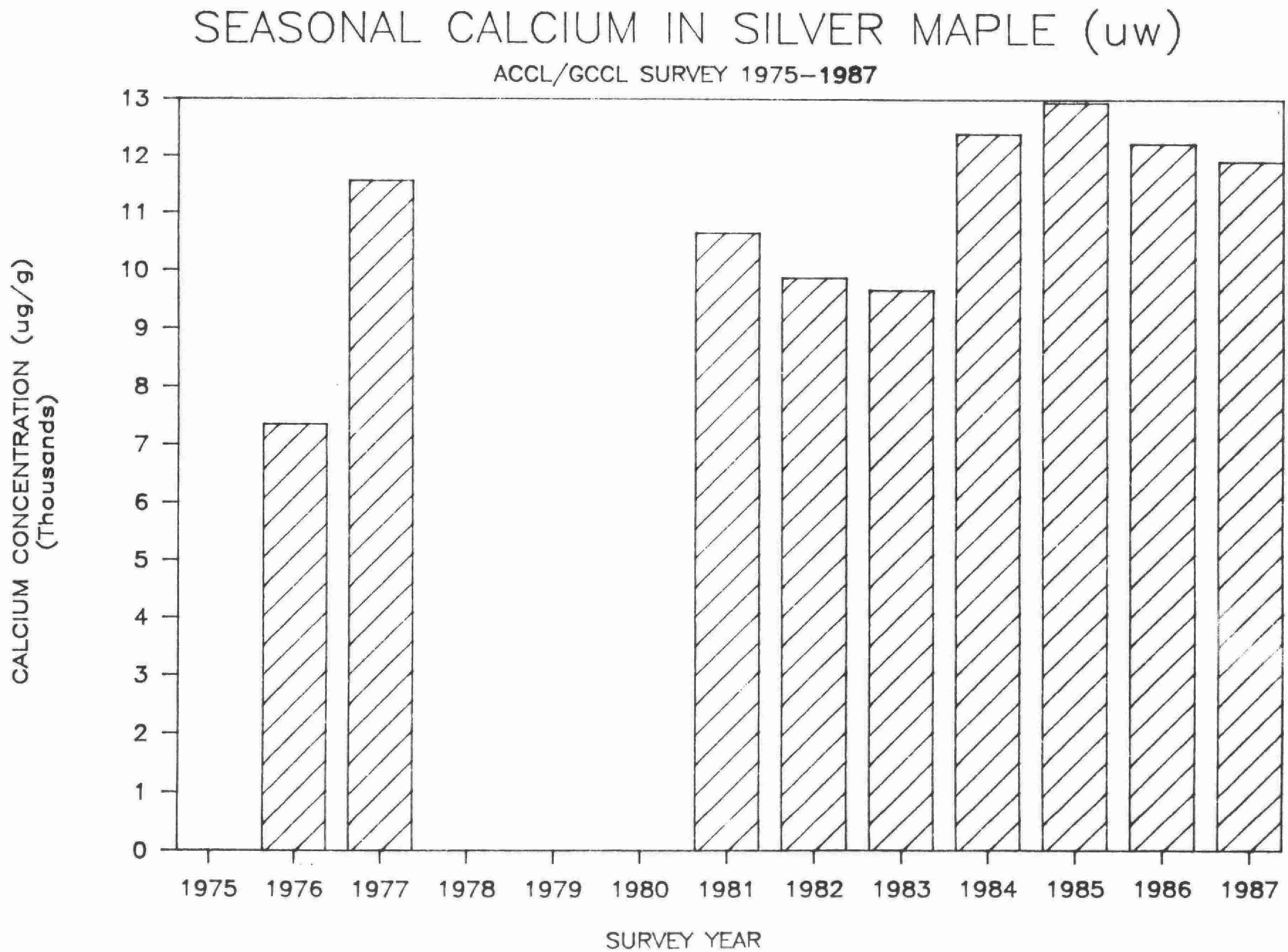
Of the sample analyses performed at the six long term stations, only fluorine in washed foliage has a complete record. This is due to the primary concern with fluoride emissions

during the early years of this survey and subsequent monitoring for compliance with the Control Orders which cited limits of fluorine in washed silver maple foliage.

Figures 13 through 17 are histograms of the seasonal average foliar concentrations of the four elements in unwashed silver maple foliage and fluorine in washed silver maple foliage. These averages are based on all samples collected at each of the six stations during the respective annual survey period, ie. six stations over five months. There are exceptions in 1977 and 1978 when all analyses were not performed on the May samples. The averages are for the available data from those years.

Reviewing the mean seasonal foliar concentrations from these six stations will provide a mechanism for assessing the effectiveness of control measures initiated by the company or companies as measured by contamination of silver maple foliage. Short term variables such as wind directions, timing of accidental releases, rainfall washing of foliage etc. are minimized.

FIGURE 13



SEASONAL CALCIUM IN SILVER MAPLE (uw)
ACCL/GCCL SURVEY 1975-1987
CALCIUM CONCENTRATION (ug/g)
(Thousands)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
SURVEY YEAR

FIGURE 14

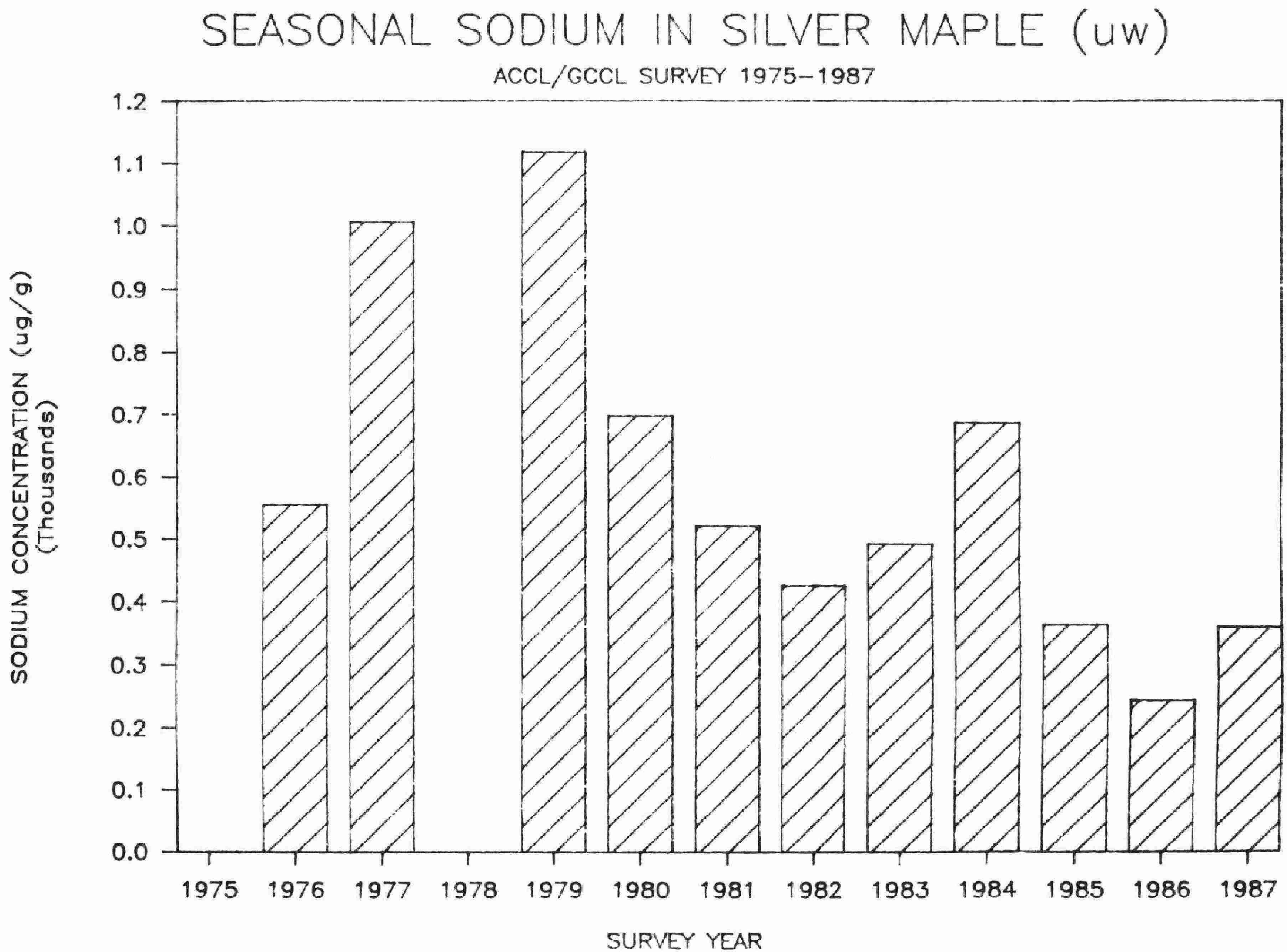

SEASONAL SODIUM IN SILVER MAPLE (uw)
ACCL/GCCL SURVEY 1975-1987
SODIUM CONCENTRATION (ug/g)
(Thousands)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
SURVEY YEAR

FIGURE 15

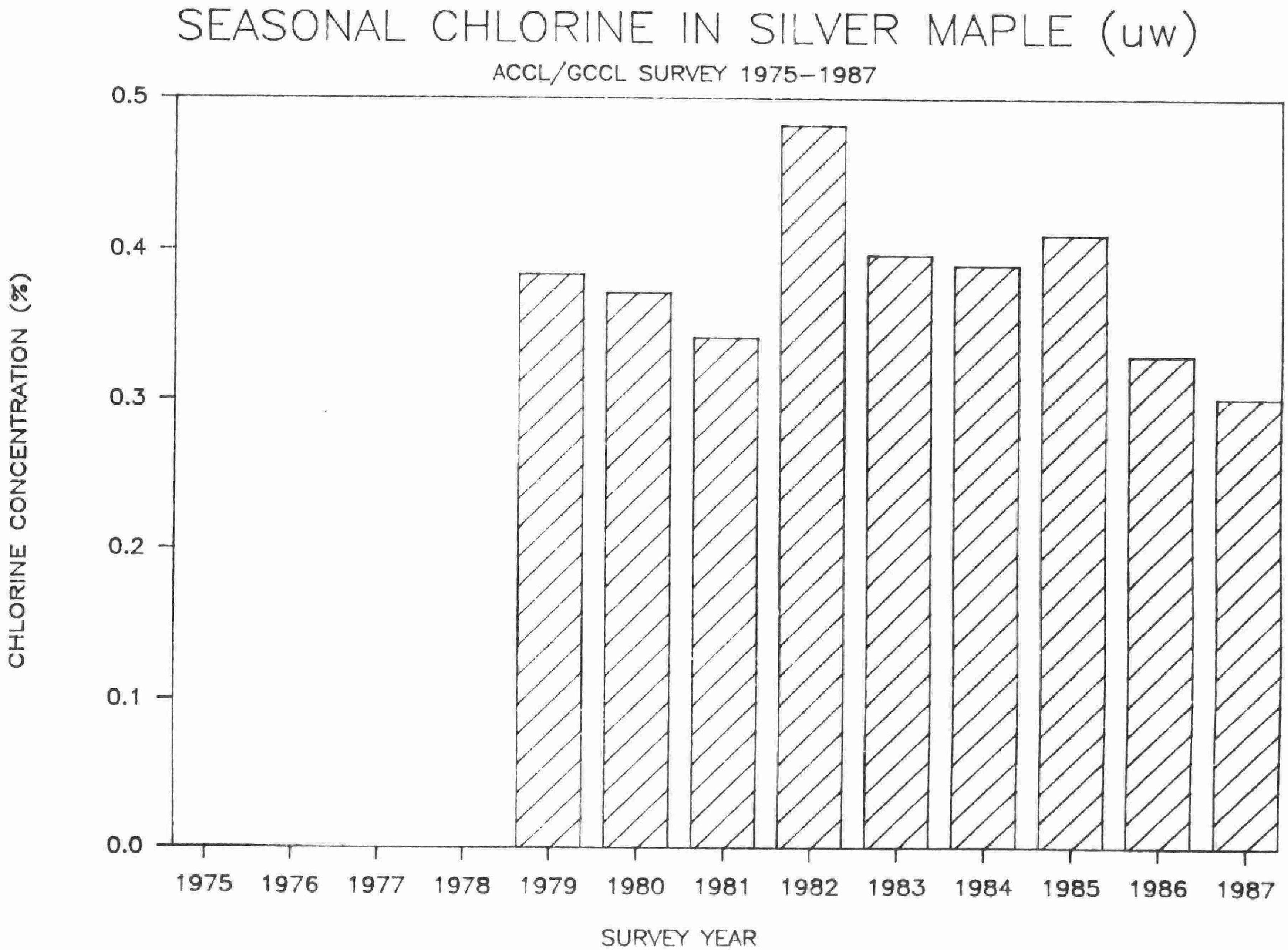

SEASONAL CHLORINE IN SILVER MAPLE (uw)
ACCL/GCCL SURVEY 1975-1987
CHLORINE CONCENTRATION (%)
0.0
0.1
0.2
0.3
0.4
0.5
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
SURVEY YEAR

FIGURE 16

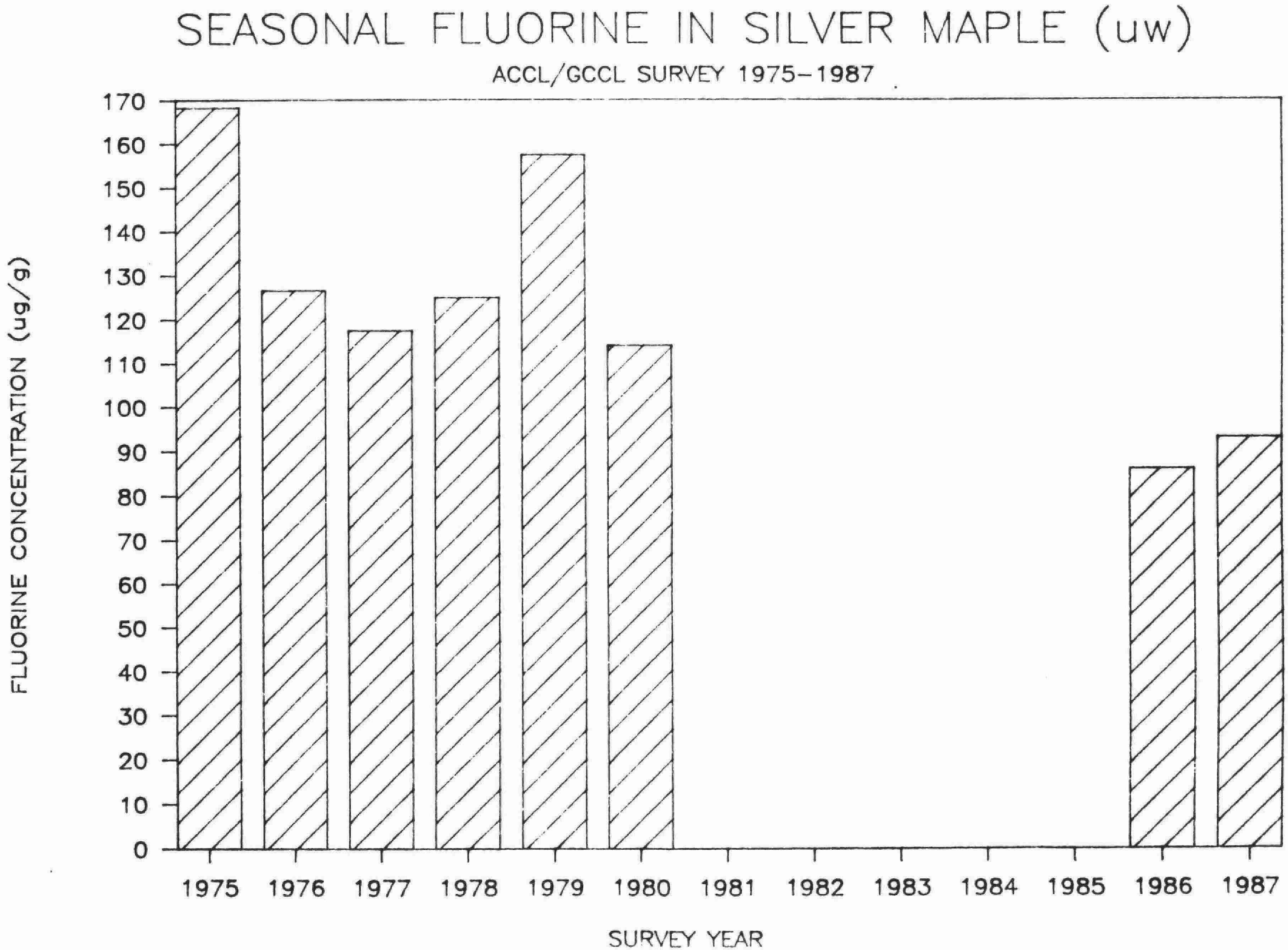
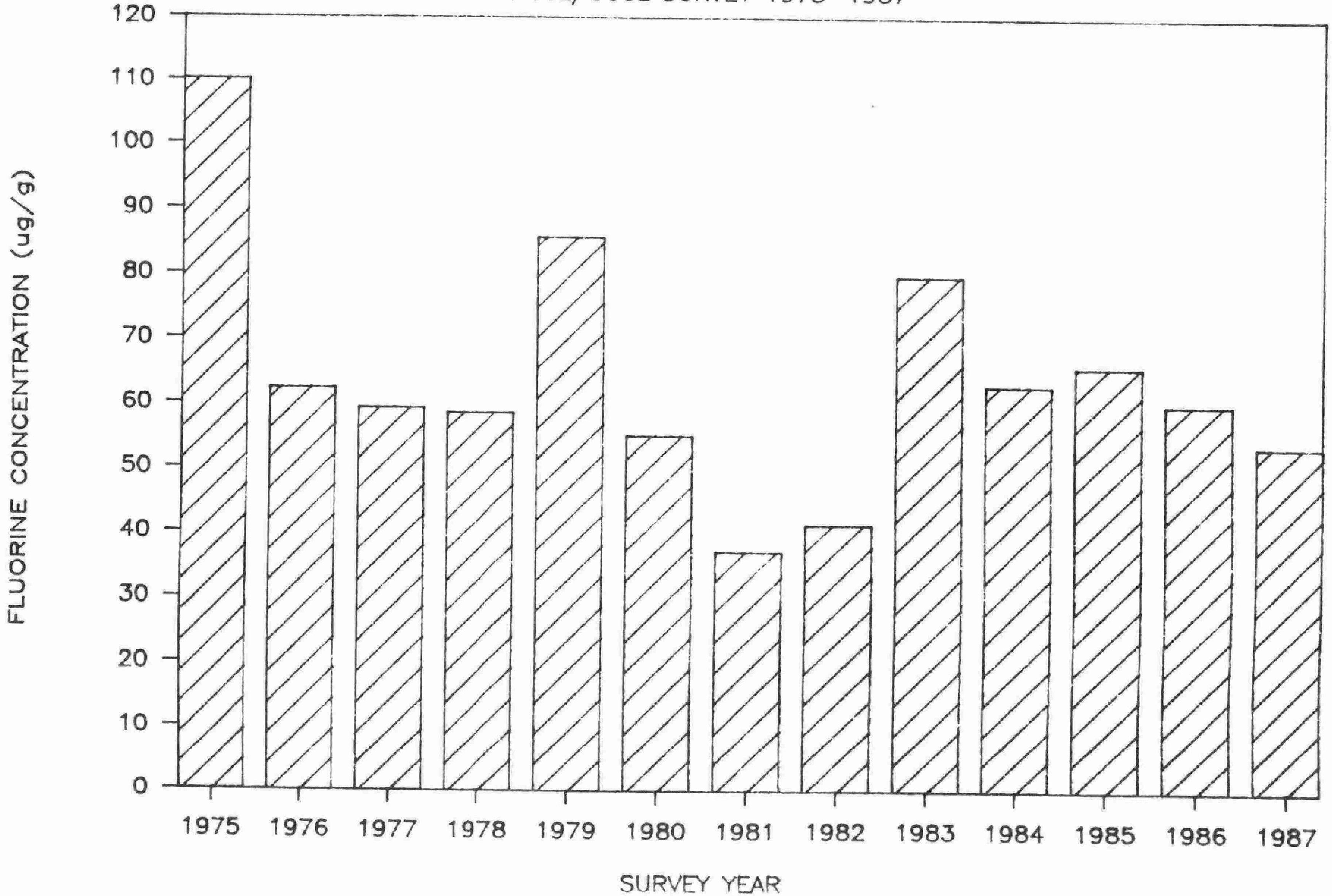

SEASONAL FLUORINE IN SILVER MAPLE (uw)
ACCL/GCCL SURVEY 1975-1987
FLUORINE CONCENTRATION (ug/g)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
SURVEY YEAR

FIGURE 17

SEASONAL FLUORINE IN SILVER MAPLE (w)

ACCL/GCCL SURVEY 1975–1987



7.1 Calcium Trends in Unwashed Silver Maple

Figure 13 indicates, with the exception of 1976, relatively constant concentrations of calcium over the years. Seasonal mean concentrations range from 10,000 to 13,000 ug/g. The seasonal trend of increasing concentrations through the growing season have been maintained, again with the exception in 1976 (see Appendix B). This strengthens the argument for physiological control of calcium concentrations overriding contributions from aerial contamination. While contamination by calcium emitted by the industry may be occurring, the high background concentrations, 1.0 to 1.3 % as dry weight, causes this potential contamination to be indiscernible by total foliage analysis.

The 1976 exceptions were due to very low September calcium concentrations at all six stations. This has reduced the seasonal average and negated the within-season trend. The original laboratory results report for the September 1976 sampling gives these low values. In the absence of another explanation for this discrepancy, it is probably due to an error in the analytical laboratory, either human or instrumental.

7.2 Sodium Trends In Unwashed Silver Maple

Sodium concentrations, Figure 14, have had considerable variation from year to year. Seasonal means exceeded the 350 ug/g urban ULN guideline in every year except 1986 and the rural ULN guideline of 50 ug/g in every year, frequently by an order of magnitude or more. These exceedences, along with the year to year variation, demonstrate that emissions of sodium compounds are a continuing source of contamination of silver maple foliage. This problem was especially severe in 1977 and 1979. The seasonal mean of 1987 is the second lowest since 1975 but even this mean still exceeds the urban ULN guideline. While notable reductions followed the peak in 1979, these were then followed by increases in 1983 and

1984. The contributions of sodium released by Canada Occidental Petroleum are inconsequential in this time trend analysis since the stations under consideration are well removed from this ground level, particulate source of sodium.

The cause of these cyclical variations is not known. Variations in industrial production rates together with ongoing chronic emissions may be one cause. Frequencies of uncontrolled releases in different years may be another.

7.3 Chlorine Trends in Unwashed Silver Maple

Seasonal mean chlorine concentrations, Figure 15, have remained relatively constant over the years with the exception of a moderately high peak in 1982 and moderate reductions in 1986 and 1987. The 1982 peak may be indicative of the start-up of the Canada Occidental Petroleum plant, although the Certificate of Approval was issued in October, 1982 and therefore after the sampling period. The actual date of start-up has not been confirmed by the author of this report.

The arrival of this new source of chlorine in the area makes it impossible to analyze the trend for chlorine emissions from the ACCL/GCCL complex. A moderate decline appeared to be developing between 1979 and 1981 but was interrupted by a notable increase in 1982. The 1987 concentrations are the lowest to date and suggest improved emission controls are having the desired effect.

However, the rural ULN guideline for chlorine of 0.15 % is regularly exceeded, even by seasonal means, by factors of two or three. Considerable reductions are still required before the ULN guideline is reached.

7.4 Fluorine Trends in Unwashed and Washed Silver Maple

When Figures 16 and 17, depicting fluorine concentrations in unwashed and washed foliage, are compared, it

becomes apparent that variations in the seasonal foliar concentrations of fluorine in both sample types coincide. This is indicative of an airborne source of fluorine with foliar absorption of a portion of the contaminant. There is, however, no indication of a trend toward reduced concentrations since 1976.

The 1987 seasonal mean of fluorine in washed foliage is very similar to the mean encountered as early as 1976. If foliar concentrations are used as a measure of the effectiveness of emission control strategies implemented by the industry, then it would appear that significant emission reductions have not occurred for 11 years. In the interim, washed foliage fluorine concentrations have been higher or lower than those encountered in 1976 and 1987. Reasons for these variations could be similar to those for the sodium variations which are believed to relate to the frequency, timing and magnitude of emissions.

While there are no ULN guidelines for washed foliage, the former Control Order limit of 100 ug/g fluorine in washed silver maple foliage can be used as a measure of significant foliar contamination. In 1975, even the seasonal mean exceeded this limit. Since then, only in 1981 and 1982 were there no individual exceedences of this limit. These years also had the lowest seasonal means.

The Phytotoxicology Section ULN guidelines for fluorine in unwashed foliage are 35 ug/g for urban samples and 15 ug/g for rural samples. Figure 16 clearly shows that these guidelines were dramatically exceeded by seasonal mean concentrations in every year since 1975 where data are available.

In summation, fluorine concentrations in both washed and unwashed silver maple foliage have been and continue to be unacceptably elevated.

8 Conclusions

Emissions from the industrial complex occupied by Allied Chemical Canada Ltd. and General Chemical Canada Ltd. in 1987 adversely affected silver maple in the vicinity of the complex. Emissions of fluoride compounds were reflected in elevated foliar concentrations of fluorine in silver maple. The former Control Order, which set a limit for fluorine concentrations in washed silver maple, was exceeded at Station 1 on each sampling date. The consistency with which relatively high or low foliar concentrations were maintained at the sampling stations indicates chronic fumigations by fluoride compounds. However, intermittent peaks in foliar fluorine at some stations indicated acute releases superimposed on the chronic background contamination. Fluoride emissions likely contributed to injury of silver maple foliage. Injury was generally rated as trace in severity.

Emissions of compounds containing sodium were also indicated, although these compounds were not necessarily or exclusively salt (NaCl). The ULN guideline for sodium was regularly exceeded. The variations in sodium concentrations in silver maple foliage indicated episodic exposure to these elements; however, chronic emissions contributed to the elevated concentrations.

Contamination of silver maple foliage by emissions of chlorine was also evident. However, the presence of a second industrial source of chlorine in the geographic area since 1982, and the probability that this source emits chlorine as a gas, precludes ascribing chlorine contamination in the wider Amherstburg area solely to the ACCL/GCCL industrial complex.

While calcium dust releases from the industrial complex occur regularly, foliar calcium concentrations were not excessive and patterns could be ascribed to natural causes. The use of foliage as a monitor of calcium contamination in this case appears to be inappropriate.

A review of historic silver maple foliage chemistry from the permanent sampling stations reveal minor if any long term trends in the concentrations of the contaminants. Sodium concentrations are at or near historic lows; however, historic lows have appeared previously only to be followed by increases in subsequent years. The concentrations have and continue to exceed the ULN guidelines and remain environmentally unacceptable.

Foliar chlorine concentrations were relatively constant from 1979 to 1987 but have had minor year-to-year variations. The 1987 chlorine concentrations are, marginally, the lowest to date. The presence of a second source of chlorine in the Amherstburg area precludes evaluation of the chlorine emission trends from the ACCL/GCCL complex. Chlorine concentrations are still substantially excessive when judged by the Phytotoxicology ULN guidelines.

Fluorine remains the main contaminant of concern with respect to emissions from the industrial complex. Fluorine in washed silver maple foliage has varied from year to year but no trend has been established. The only notable change in fluorine concentrations was a reduction from the very high concentrations of 1975. Fluorine in unwashed foliage has an incomplete record but these concentrations parallel the washed foliage concentrations.

Fluorine concentrations have and continue to be highly excessive relative to the Phytotoxicology Section ULN guideline for unwashed foliage and the former Control Order limit for washed foliage. On the basis of these findings, it is concluded that emission reduction initiatives have not been sufficiently effective to cause a discernable reduction in foliar contamination or to eliminate the potential for injury to vegetation in the area surrounding the ACCL/GCCL industrial complex.

9 Recommendations

The Phytotoxicology Section has been conducting annual surveys in the vicinity of the ACCL/GCCL industrial complex since 1970. Vegetation contamination and injury by industrial emissions have been regularly documented. There has not been any noticeable trend toward emission reductions as reflected by decreases in contaminant concentrations in silver maple foliage. On the basis of these findings, additional action by the Ministry of Environment is warranted to encourage the companies responsible for these emissions to improve their control strategies.

If abatement actions are taken, Phytotoxicology Section monitoring should continue, with the survey being redesigned to improve its capability for ascribing vegetation contamination to the two separate but proximal sources in the Amherstburg area. This would include a new integrated station network with more comprehensive coverage of the area.

While foliage chemistry is a useful medium for detecting contamination by certain types of emissions, it apparently is not useful for detecting calcium contamination in the vicinity of the ACCL/GCCL complex. A network of non-biologic, passive or active monitors would be required to quantify ambient air concentrations of calcium compounds or of specific contaminants such as HCl, HF, Cl_2 or fluorocarbons.

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Appendix A

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Appendix B

Summary of Historic Silver Maple Foliage Chemistry in the Vicinity of Allied Chemical Canada Ltd. and General Chemical Canada Ltd., Amherstburg

		Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
CALCIUM (unwashed)												
	May											
	Jun											
1975	Jul	not determined										
	Aug											
	Sep											
	May	2300	12100	4530	4000	3200	4200	5055		4400		
	Jun	1900	3000	3000	4300	2100	3500	2967		2500		
1976	Jul	6500	9900	11600	12300	4500	7100	8650	7358	9300		
	Aug	15300	28200	15600	23400	10600	15100	18033		16800		
	Sep	1300	4600	1730	1900	1470	1500	2083		2000		
	May											
	Jun	3700	9900	6500	11100	5900	5800	7150		5100		
1977	Jul	2500	6600	6300	5800	3600	5000	4967	11558			
	Aug	13900	15200	11100	9700	15800	29700	15900				
	Sep	10000	29000	18300	21000	14700	16300	18217				
	May											
	Jun											
1978	Jul	not determined										
	Aug											
	Sep											
	May											
	Jun											
1979	Jul	not determined										
	Aug											
	Sep											
	May											
	Jun											
1980	Jul	not determined										
	Aug											
	Sep											
	May	7900	15000	7700	8400	8600	5900	8917			8800	
	Jun	8600	16000	8400	10000	9500	7600	10017			9400	
1981	Jul	6600	17000	12500	11200	7900	7900	10517	10657		11900	
	Aug	8000	13000	12000	13000	9600	12200	11300			13000	
	Sep	10000	16000	13000	16000	7200	13000	12533			14000	
	May	4200	7900	4600	6800	5300		5760			5600	
	Jun	6300	6800	5800	9000	9100	6400	7233			7800	
1982	Jul	5900	14900	9600	15400	11300	8000	10850	9882		7000	
	Aug	10400	18600	13300	12000	14100	12200	13433			12800	
	Sep	6000	15600	12400	11400	12800	14600	12133			8700	

Historic Silver Maple Foliage Chemistry - ACCL/GCCL

Year	Month	Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May	5300	8900	4200	6800	3700	8800	6283		1000	4500	
	Jun	5900	8600	6300	7000	5800	9100	7117		6600	7200	
1983	Jul	8700	9100	10800	9300	9300	10200	9567	9670	10600	9100	
	Aug	8900	15600	13100	12500	10400	12300	12133		13100	12900	
	Sep	9000	15300	14000	13100	11700	16400	13250		13000	11800	
	May	4900	8400	6600	6600	4900	8300	6617		6100	4800	
	Jun	8200	12000	8200	9600	7500	13300	9800		9500	8800	
1984	Jul	9400	13700	12700	13300	11300	13300	12283	12403	11300	10200	
	Aug	9000	16300	13700	15300	13000	20000	14550		13300	15700	
	Sep	14700	22700	16300	23300	16300	19300	18767		16000	19000	
	May	8000	10400	7300	9100	6800	8400	8333		7000	9900	
	Jun	6200	14300	13700	11700	8800	12700	11233		11600	11000	
1985	Jul	5600	15000	12000	10700	9300	16700	11550	12947	12700	10600	
	Aug	8800	17000	13300	13300	12300	16700	13567		17600	14600	
	Sep	12300	25000	19000	24000	16000	24000	20050		22000	15300	
	May	6400	9800	7600	6900	6000	9100	7633		6200	7100	
	Jun	11300	15300	10500	12700	8400	11300	11583		10300	11900	
1986	Jul	9300	15700	13000	10000	9700	10700	11400	12237	11000	11600	
	Aug	9200	15700	19300	14300	11100	15700	14217		12000	14000	
	Sep	10400	19300	29700	8400	14000	16300	16350		18700	17300	
	May	8400	8400	6100	7000	6900	9900	7800		7000	7600	6700
	Jun	7200	10300	6800	10100	7800	10500	8800		10300	11300	8300
1987	Jul	8600	14300	10300	13700	10800	13700	11900	11920	12400	10700	11000
	Aug	10500	11300	13300	19300	14000	20000	14700		14700	13300	11700
	Sep	14000	16000	12300	20000	13300	22700	16400		19300	21000	15000

SODIUM (unwashed)

Year	Month	Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May											
	Jun											
1975	Jul	not determined										
	Aug											
	Sep											
	May	640	870	340	310	350	700	535				
	Jun	690	340	330	170	110	1140	463				
1976	Jul	290	380	620	250	150	730	403	555			
	Aug	300	1000	810	430	280	2040	810				
	Sep	330	1830	590	120	240	270	563				
	May											
	Jun	400	840	490	290	410	900	555				
1977	Jul	640	1930	1250	270	520	1940	1092	1006			
	Aug	1080	810	300	480	520	8600	1965				
	Sep	330	390	460	210	340	740	412				
	May											
	Jun											
1978	Jul	not reported										
	Aug											
	Sep											
	May	622	5200	335	290	959	460	1311				
	Jun	240	1330	380	320	680	2600	925				
1979	Jul	860	450	250	350	980	2900	965	1118			
	Aug	610	380	470	430	1740	2400	1005				
	Sep	1710	1440	1030	365	1830	1930	1384				
	May	580	810	680	270	380	710	572			163	
	Jun	930	880	253	380	1170	2590	1034			156	
1980	Jul	265	590	180	470	395	835	456	697		176	
	Aug	800	600	280	280	590	900	575			106	
	Sep	350	1140	255	420	480	2440	848			220	
	May	700	1060	910	271	450	390	630			160	
	Jun	400	450	250	129	350	1780	560			80	
1981	Jul	190	710	217	88	167	400	295	520		217	
	Aug	400	350	580	173	320	1260	514			80	
	Sep	420	1150	400	350	200	1070	598			125	
	May	440	310	440	450	310	1180	522			70	
	Jun	242	220	200	137	204	340	224			67	
1982	Jul	163	410	270		150	440	287	424		37	
	Aug	228	885	244	540	218	1300	569			47	
	Sep	236	700	310	840	300	740	521			265	

Historic Silver Maple Foliage Chemistry - ACCL/GCCL

		Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May	1607	657	153	207	320	1567	752		463	110	
	Jun	297	133	83	80	213	1663	412		277	50	
1983	Jul	270	283	109	130	160	623	263	491	117	63	
	Aug	250	440	160	323	170	1407	458		127	97	
	Sep	470	390	497	313	327	1440	573		157	93	
	May	293	733	200	167	207	1533	522		207	120	
	Jun	890	450	163	110	177	2167	660		177	90	
1984	Jul	1167	500	147	147	573	867	567	686	250	91	
	Aug	687	820	200	137	483	2733	843		157	81	
	Sep	980	1600	380	237	400	1433	838		423	183	
	May	390	577	377	287	533	397	427		137	88	
	Jun	403	187	530	99	267	640	354		156	64	
1985	Jul	267	293	167	78	307	500	269	362	115	55	
	Aug	193	347	170	76	287	507	263		137	70	
	Sep	390	810	323	333	570	567	499		253	65	
	May	227	247	317	123	157	293	227		120	60	
	Jun	457	167	120	63	193	540	257		109	93	
1986	Jul	577	377	137	40	106	233	245	243	153	47	
	Aug	197	163	500	113	170	237	230		72	64	
	Sep	124	320	203	69	243	587	258		90	84	
	May	457	187	170	250	507	1733	551		110	79	27
	Jun	370	130	127	47	140	533	225		123	74	31
1987	Jul	620	127	98	120	112	327	234	358	113	440	26
	Aug	207	393	172	64	147	883	311		73	78	57
	Sep	527	840	150	303	263	747	472		170	92	60

CHLORINE (unwashed)

		Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May											
	Jun											
1975	Jul	not determined-washed only										
	Aug											
	Sep											
	May											
	Jun											
1976	Jul	not determined-washed only										
	Aug											
	Sep											
	May											
	Jun											
1977	Jul	not determined-washed only										
	Aug											
	Sep											
	May											
	Jun											
1978	Jul	not determined-washed only										
	Aug											
	Sep											
	May	0.23	0.60	0.12	0.22	0.21	0.15	0.26				
	Jun	0.32	0.60	0.23	0.41	0.24	0.53	0.39				
1979	Jul	0.42	0.45	0.31	0.40	0.26	0.62	0.41	0.38			
	Aug	0.33	0.44	0.33	0.31	0.22	0.47	0.35				
	Sep	0.67	0.70	0.33	0.43	0.33	0.63	0.52				
	May	0.31	1.04	0.41	0.39	0.29	0.36	0.47			0.07	
	Jun	0.24	0.46	0.21	0.29	0.25	0.39	0.31			0.07	
1980	Jul	0.34	0.39	0.19	0.50	0.20	0.40	0.34	0.37		0.06	
	Aug	0.45	0.52	0.29	0.49	0.20	0.52	0.41			0.09	
	Sep	0.43	0.36	0.29	0.29	0.21	0.43	0.33			0.09	
	May	0.26	0.55	0.28	0.27	0.10	0.29	0.29			0.11	
	Jun	0.3	0.5	0.1	0.3	0.1	0.4	0.28			0.1	
1981	Jul	0.3	0.6	0.6	0.5	0.1	0.5	0.43	0.34		0.2	
	Aug	0.4	0.7	0.8	0.5	0.1	0.5	0.50			0.2	
	Sep	0.4	0.2	0.1	0.1	0.1	0.3	0.20			0.1	
	May	0.20	0.34	0.19	0.26	0.17	0.36	0.25			0.09	
	Jun	0.3	0.4	0.2	0.3	0.2	0.4	0.30			0.1	
1982	Jul	0.4	1.4	0.4		0.5	0.5	0.64	0.48		0.2	
	Aug	0.5	1.0	0.4	0.7	0.4	0.8	0.63			0.3	
	Sep	0.4	0.7	0.7	0.6	0.4	0.7	0.58			0.5	

		Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May	0.3	0.4	0.2	0.3	0.2	0.5	0.32		0.2	0.1	
	Jun	0.3	0.3	0.2	0.3	0.2	0.5	0.30		0.1	0.1	
1983	Jul	0.3	0.4	0.3	0.3	0.3	0.5	0.35	0.40	0.1	0.2	
	Aug	0.2	0.8	0.3	0.5	0.4	0.7	0.48		0.1	0.2	
	Sep	0.4	0.8	0.4	0.7	0.1	0.8	0.53		0.2	0.3	
	May	0.2	0.3	0.2	0.3	0.1	0.3	0.23		0.1	0.1	
	Jun	0.3	0.4	0.2	0.3	0.2	0.4	0.30		0.1	0.1	
1984	Jul	0.4	0.5	0.3	0.4	0.2	0.4	0.37	0.39	0.2	0.1	
	Aug	0.3	0.9	0.4	0.4	0.2	0.6	0.47		0.2	0.2	
	Sep	0.5	0.9	0.5	0.6	0.3	0.7	0.58		0.3	0.3	
	May	0.2	0.4	0.2	0.3	0.1	0.3	0.25		0.1	0.1	
	Jun	0.2	0.4	0.4	0.3	0.1	0.5	0.32		0.1	0.1	
1985	Jul	0.2	0.8	0.4	0.4	0.1	0.5	0.40	0.41	0.1	0.2	
	Aug	0.3	1.0	0.5	0.4	0.3	0.6	0.52		0.2	0.2	
	Sep	0.4	0.9	0.7	0.5	0.3	0.6	0.57		0.2	0.3	
	May	0.2	0.4	0.3	0.2	0.1	0.2	0.23		0.1	0.1	
	Jun	0.3	0.4	0.4	0.2	0.1	0.3	0.28		0.1	0.1	
1986	Jul	0.2	0.5	0.4	0.5	0.1	0.2	0.32	0.33	0.1	0.2	
	Aug	0.3	0.6	0.7	0.7	0.1	0.3	0.45		0.1	0.2	
	Sep	0.3	0.5	0.6	0.2	0.2	0.4	0.37		0.1	0.3	
	May	0.20	0.38	0.17	0.24	0.17	0.34	0.25		0.08	0.07	0.11
	Jun	0.23	0.33	0.34	0.21	0.12	0.24	0.25		0.10	0.11	0.35
1987	Jul	0.35	0.40	0.25	0.28	0.08	0.26	0.27	0.30	0.11	0.13	0.49
	Aug	0.40	0.57	0.35	0.37	0.07	0.39	0.36		0.11	0.16	0.47
	Sep	0.04	0.54	0.42	0.49	0.13	0.69	0.39		0.16	0.20	0.39

FLUORINE (unwashed)

Year	Month	Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May	240	99	31	62	58	76	94		14		
	Jun	116	273	50	67	41	102	108		51		
1975	Jul	240	232	83	572	118	340	264	168	191		
	Aug	280	287	74	226	79	224	195		109		
	Sep	235	313	85	138	106	200	180		125		
	May	87	293	142	54	38	62	113		75		
	Jun	121	51	76	51	25	46	62		116		
1976	Jul	107	199	102	216	42	56	120	127	93		
	Aug	274	344	135	343	86	141	221		93		
	Sep	227	225	65	107	33	51	118		149		
	May	69	253	216	156	143	263	183		36		
	Jun	35	61	26	77	31	50	47		16		
1977	Jul	70	106	80	95	52	63	78	117			
	Aug	245	119	90	405	102	138	183				
	Sep	141	116	88	107	55	72	97				
	May											
	Jun	116	36	11	67	45	68	57				
1978	Jul	126	97	47	64	77	130	90	125			
	Aug	562	178	57	130	63	177	195				
	Sep	307	272	89	122	85	74	158				
	May	32	65	39	26	90	44	49				
	Jun	333	102	55	69	82	154	133		12		
1979	Jul	182	78	81	43	51	190	104	158			
	Aug	362	335	164	107	126	168	210		52		
	Sep	497	468	164	112	94	413	291				
	May	41	305	127	26	28	255	130			11	
	Jun	134	46	24	112	48	200	94			14	
1980	Jul	107	37	24	43	19	89	53	114		16	
	Aug	255	80	83	128	70	255	145			39	
	Sep	325	62	77	88	97	235	147			42	
	May											
	Jun											
1981	Jul	not reported										
	Aug											
	Sep											
	May											
	Jun											
1982	Jul	not reported										
	Aug											
	Sep											

		Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May											
	Jun											
1983	Jul	not reported										
	Aug											
	Sep											
	May											
	Jun											
1984	Jul	not reported										
	Aug											
	Sep											
	May											
	Jun											
1985	Jul	not reported										
	Aug											
	Sep											
	May	81	74	70	41	59	82	68		11	6	
	Jun	180	76	67	57	34	74	81		56	26	
1986	Jul	274	39	50	21	28	54	78	86	36	21	
	Aug	263	80	116	85	84	91	120		60	39	
	Sep	250	63	58	18	44	67	83		57	46	
	May	346	69	59	29	44	156	117		44	15	4
	Jun	212	33	36	29	19	74	67		42	13	10
1987	Jul	311	34	29	95	43	86	100	93	42	11	8
	Aug	203	34	33	27	20	62	63		24	14	9
	Sep	223	67	61	190	58	109	118		48	32	17

FLUORINE (washed)

Year	Month	Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May	161	54	19	79	47	36	66		14		
	Jun	116	131	24	43	32	68	69		39		
1975	Jul	240	151	39	225	61	187	151	110	118		
	Aug	280	167	42	125	46	113	129		76		
	Sep	235	208	47	97	66	165	136		70		
	May	49	163	78	24	20	42	63		33		
	Jun	75	32	50	34	18	26	39		51		
1976	Jul	71	39	47	83	16	28	47	62	34		
	Aug	129	153	59	137	35	66	97		49		
	Sep	141	110	33	59	20	31	66		60		
	May	41	84	84	85	46	73	69		17		
	Jun	39	54	33	79	32	45	47		16		
1977	Jul	42	48	35	60	35	44	44	59			
	Aug	113	49	53	126	44	59	74				
	Sep	88	91	46	64	40	43	62				
	May											
	Jun	78	18	8	48	23	31	34				
1978	Jul	64	21	13	29	34	47	35	58			
	Aug	195	43	25	36	30	48	63				
	Sep	181	157	53	108	62	51	102				
	May	17	14	6	11	51	28	21				
	Jun	191	34	21	29	51	95	70		8		
1979	Jul	144	40	35	32	42	111	67	86			
	Aug	265	156	77	61	63	135	126		17		
	Sep	282	198	98	65	49	168	143				
	May	15	100	33	12	12	108	47			5	
	Jun	76	22	14	46	28	114	50			10	
1980	Jul	72	15	14	30	13	45	32	55		9	
	Aug	143	30	34	84	55	118	77			22	
	Sep	147	28	36	45	53	107	69			22	
	May	10	57	9	11	15	15	20			6	
	Jun	85	62	42	40	20	30	47			10	
1981	Jul	38	46	20	40	10	35	32	37		20	
	Aug	55	26	50	58	30	26	41			22	
	Sep	76	74	38	48	12	30	46			14	
	May	33	14	25	28	29	62	32			14	
	Jun	34	24	17	16	20	58	28			20	
1982	Jul	50	50	25	41	31	48	41	41		11	
	Aug	46	62	27	58	24	31	41			18	
	Sep	92	66	33	86	32	74	64			43	

		Stn 1	Stn 16	Stn 18	Stn 29	Stn 30	Stn 31	MONTH AVG	SEASON AVG	Stn 32	Stn 12	Stn 65
	May	15	17	20	30	9	62	26		3	12	
	Jun	55	17	11	34	9	150	46		8	5	
1983	Jul	158	25	22	49	32	89	63	80	25	10	
	Aug	86	51	55	65	45	240	90		39	19	
	Sep	447	117	99	147	76	160	174		66	26	
	May	166	10	16	20	11	17	40		18	10	
	Jun	213	20	17	22	8	55	56		26	8	
1984	Jul	264	27	26	38	21	68	74	63	41	12	
	Aug	138	20	40	47	15	40	50		43	14	
	Sep	317	38	51	65	23	72	94		71	24	
	May	218	39	21	45	24	43	65		23	7	
	Jun	100	54	39	21	14	45	46		40	7	
1985	Jul	144	59	24	51	30	73	64	66	32	10	
	Aug	60	105	39	55	18	98	63		47	15	
	Sep	225	107	61	59	40	60	92		48	22	
	May	70	24	19	29	47	53	40		9	4	
	Jun	98	34	36	25	24	37	42		31	15	
1986	Jul	140	20	28	13	19	26	41	60	23	13	
	Aug	191	93	113	76	54	50	96		40	30	
	Sep	270	64	52	16	33	44	80		49	43	
	May	194	38	29	17	18	61	60		32	8	3
	Jun	126	24	27	21	13	51	44		35	9	8
1987	Jul	161	18	18	42	14	29	47	53	28	9	4
	Aug	153	26	24	26	23	44	49		27	13	11
	Sep	140	46	48	75	38	60	68		43	27	14